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CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions and bibliography, including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (a) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (b) abstracts or reviews of important meteorological papers and books; and (c) notes. In each issue of the REVIEW abstracts, reviews, and notes are grouped by subjects, roughly, in the following order: General work, observations, and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but **the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW OR SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations, and others containing monographs or specialized groups of papers, are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement, some experimental results and a theory—each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. The attached addressed franked slip may be used for this purpose, or one may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.

SUPPLEMENT No. 3.

CORRIGENDUM.

REVIEW, August 1920.

Page 460, Table 1, year 1916, last column, "55.4" *should read* "57.1".

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

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DECEMBER, 1920.

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ATMOSPHERIC ENVIRONMENT AND HEALTH.[1]

By Dr. LEONARD HILL.

[Osborne House, Loughton, Essex, England, Dec 18, 1920.]

The wild animal which survives in the struggle for existence enjoys perfect fitness and health. On the other hand civilized man requires a volume to contain the list of diseases from which he suffers. Not only wild but domestic animals—horses, cattle, sheep, swine—do well on an open-air existence; they are far more subject to disease when closely confined in stalls. Stock breeders have not succeeded in using successfully artificial heat for the raising of stock, excepting the case of young chickens hatched in incubators. The experience of keepers of zoological gardens has led them to extend the opportunities of open-air life, in the case of animals brought from tropical countries.

Man, evolved some million years ago, has immense inborn power of resisting cold. The experience of shipwrecked people, and of citizen-soldiers exposed to the utmost rigors of weather in the trenches, shows this power. The soldiers in the great war, well-fed, clothed and exercised but at times wet, chilled and exhausted by war, were, compared to the civilian population at at home, exceptionally free from respiratory catarrh. Wild men, such as the Fuegians, stand exposure to most inclement weather with scanty or no clothing and no houses or artifical heat. They practice infanticide to keep the population down to the food supply. They, like the wild animal, shelter in thickets, or caves, where, owing to wind and temperature difference between their bodies and the atmosphere, there is free exchange of air.

The experience of open-air schools and sanatoria show that life spent largely in the open benefits the health of those subject to catarrhs, those with overnervous temperament, those with heart weakness, etc. London has two and New York not less than 120 such schools. The Japanese have carried out their wonderful development of artistic excellence in craftsmanship in slightly built dwellings with the aid, in cold weather, of nothing but charcoal braziers to warm their hands at, depending on clothes and exercise to keep their bodies warm. On the other hand, the endeavor in the last century or so of Europeans and Americans dwelling in the colder climates, has been toward building draughtless houses and securing inside these by artificial heating a climate similar to that on a still, oppressive warm summer day. The low cooling power of stagnant air of rooms artificially heated by radiators depresses the metabolism to a low level. In place of the body being kept warm naturally by the stimulation of cool air exciting muscular exercise and glanular activity and so enhancing the combustion of food, it is kept warm by the blanketing effect of warm stagnant air, so that sedentary occupations, amusements and rest can be carried out in warm comfort and a minimum of open-air muscular exercise be taken.

The body is fashioned by nature for the getting of food by active exercise, and upon the taking of such exercise depends the proper vigorous function of the digestive, respiratory and vascular organs. Consequent on this, too, is the vigor of the nervous system and keen enjoyment of life. So, too, the healthy state of joints, muscles and ligaments, and freedom from rheumatic pains depend upon proper exercise of the body, neither over use nor under use, either of which may be associated with mal-nutrition and lowered resistance to infection. The hothouse conditions of life suitable for the failing powers of the aged, the injured in a state of shock and those in the last stages of wasting disease are mistakenly supposed to be suitable for the young and healthy. The traditional fear of cold is handed down from mother to children at her knee. For fear of their "catching cold," they are confined indoors and overclothed. They are debilitated and exposed at the same time to massive infection in crowded places. They require well-chosen food containing all those vitamines or principles of growth which are found in milk, the young green shoots of plants, grain foods with the germ and outer layers not removed by the miller. At the same time they require the stimulation of abundant open-air exercise to make them eat and metabolize their food. Household expenses will go up as more food is eaten by children excited by open-air exercise to keep appetite, but an immense national economy will result from a healthy, vigorous, efficient people.

Man, with his erect posture, has to withstand the influence of gravity, which weighs down his viscera and tends to make his blood and body fluids sink to the lower parts. This influence is naturally resisted by the tone of the muscles, skin, and other membranes which by confining the body prevent overdistension of dependent parts, and by muscular exercise, such as walking, and the consequent deep breathing, which together pump the blood back from the capillaries and peripherial veins to the heart, and at the same time most effectually massage the abdominal viscera. Such massage keeps the circulation active through the bowels, liver, etc., and helps those movements of the bowels which further the proper digestion and absorption of food and prevent constipation. Unnatural bacterial fermentations, with consequent poisoning, arise in the bowels from lack of exercise, particularly in those who indulge in the pleasures of the table. Food is taken by these which is not absorbed and

[1] Submitted for presentation before American Meteorological Society, Chicago, Ill., Dec. 29, 1920. To be published also in the *International Red Cross Journal*. See also "The science of ventilation and open-air treatment," Medical Res. Counc., Special Report Series, No. 52, 295 pp., London, 1920; noted in MO. WEATHER REV., Sept., 1920, 48: 498-499; and reviewed at length in *Nature* (London), Jan. 6, 1920, pp. 601-603.

utilized. In others appetite is reduced by the sedentary indoor life and constipation and dyspepsia result with a condition of deficient feeding and the debility of the semi-starved. The deep breathing excited by exercise not only furthers the circulation and the activity of the bowels, liver, etc., but secures the proper functioning of an adequate blood stream through all parts of the lungs.

Out of doors the skin is cooled and dried by the wind and water is evaporated from it—the wind freely ventilating the clothes. The air on the most calm and oppressive day out of doors is never as still as it is in a shut-up room. The skin is also warmed by the radiant energy of the sun, and this, too, actively causes evaporation. The wind and the sun affect the flow of water from lymph and blood through the skin, the wind cools the blood in one part, the sun warms it in another, the shorter sun rays act chemically on the white skin as evidenced by sunburn and pigmentation. There is reason to think that the skin is a great seat of production of immune substances which protect us against infection. Exposure of the skin to sun and wind has a profound effect upon it, and through it on the health of the body. Cool winds insure the removal of the body heat by convection, and keep the cutaneous vessels constricted so that the blood is driven in greater volume through the viscera; the sun and warmth dilate the cutaneous vessels and enhance the flow through the skin, and excite perspiration. These to-and-fro changes of the skin's condition make for health. The monotonous life spent in an environment of overwarm, stagnant, and moist air entangled in their clothes when people are confined in rooms, often crowded, is contrary to those naturally changing conditions which pertain out of doors. The air which is breathed into the lungs, whatever be its content of moisture or its temperature, is breathed out approximately at body temperature and saturated with moisture at this temperature. What matters to the skin and respiratory membrane is not the relative humidity, but the actual vapor pressure of the air which comes in contact with it. Cold saturated air is excessively dry when warmed up to body temperature, and takes up much moisture from the body; warm saturated air (or even half-saturated), far less.

The vapor pressure of saturated air at 20° C. is 0.96 mm. Hg.; at −10° C., 2.16; at 0° C., 4.58; at 10° C., 9.21; at 20° C., 17.54; at 30° C., 31.83; at 35° C., 42.2; at 40° C., 55.3. A cubic meter of air can hold approximately as many grams of water when saturated as shown by the vapor pressure figures just given. The breathing of cool air entails, then, much greater evaporation from respiratory membrane and consequent greater flow of lymph through and secretion of fluid from it. The membrane is better washed and kept clean from infecting microbes by such outflow. The breathing of cold air entails, too, the greater flow of arterial blood through the membrane in order to keep it warm, and at the same time warm the inhaled air. Vigorous open-air exercise may increase the volume breathed five times, and this on a cold day means far more blood, lymph and secretion fluid washing the respiratory membrane. The open-air worker is thus better protected, while he escapes the massive infection from "carriers" which occurs in shut-up rooms. It is the bronchitic with chronic inflammation and those with acute catarrh who should not expose themselves to the change of atmosphere between room and wintry out of doors. What suits the bronchitic and those in the state of "chill" from infectious catarrh must not be taken as suitable for the healthy.

For them dryness of cold air is not trying, for the Alpine resorts are most bracing and health-giving. In the sirocco in Palestine the relative humidity sank to 2 per cent, the temperature being 43° C. In the Alpine winter midday the physiological saturation deficit may be even lower, that is, the difference between the vapor pressure of the air and the vapor pressure of the air saturated at body temperature, that is owing to the small amount of vapor held in the air at the low temperature there pertaining (Dorno). One gram of water evaporated takes away 600 calores of heat, so the sweating mechanism is very effectual, but it must fail in *saturated* atmospheres at temperatures at or near to body temperature. In hot, dry atmospheres it may become exhausted, especially in the sick, e. g., those suffering from constipation, malaria, etc. A wet sheet put on the body, and a fan set to blow on this, prevents heat stroke in a hot, dry atmosphere by setting up an artificial evaporation. A hot, dry wind may heat the body by convection more than it can be cooled by the evaporation of sweat; to prevent this effect Arabs, in a sandstorm, crouch on the desert and cover themselves with their robes. Moist, warm atmospheres are trying and reduce the efficiency of workers, because of the difficulty of getting rid of body heat. If the air is stagnant, the layer entangled in the clothes becomes saturated and raised to skin temperature.

Wet-bulb temperatures in factories and mines are physiologically much more important than dry-bulb temperatures; so too the vapor-pressure reading is much more important than the relative humidity, and the velocity of movement of the air is most important of all, for on this chiefly depends cooling by convection and evaporation. The dry-bulb thermometer indicates the average effect of the temperature of the air and walls of the inclosure on itself; it does not show the cooling and evaporative power of the environment on the skin and respiratory membrane. It is a static instrument while the body is dynamic, producing heat which must be lost at an equal rate. To measure cooling and evaporative powers, I have introduced the kata thermometer, a large-bulbed spirit thermometer of standard size and shape, graduated between 100° and 95° F. The bulb is heated in hot water in a Thermos flask until the meniscus rises into the small top of the bulb. It is then dried, suspended, and the time of cooling from 100° to 95° F. taken with a stop watch in seconds. The number of seconds divided into a factor number (approximately 500, and determined for each instrument) gives the cooling power by convection and radiation on the surface of the "kata" at approximately skin temperature in millicalories per square centimeter per second. The operation is repeated with a cotton muslin finger stall on the bulb and the wet "kata" cooling power obtained, a cooling power due to evaporation, radiation, and convection.

The difference between the two gives the evaporative cooling power. In Britain the mean dry "kata" cooling power on the top of observatories is from 20° to 25° (F.) in July and August, and about 40° (F.) in December and January. Extensive observation shows that the dry "kata" cooling power is about 6 in ordinary rooms occupied by sedentary workers. It certainly should not be less than 6 excepting under conditions of outside temperature which make it impossible to secure such a cooling power by means of fan ventilation. It is frequently found to be as low as 4 and even 3 in factories and offices when proper attention to ventilation would easily secure readings of 6.

When physical work is being done the reading should be higher, say 7 or 8 and even more when labor is being performed. By keeping the cooling power in proper relation to the work done and heat output of the worker—four times as much energy is spent by the body in heat as in doing external work—the latter can be kept from sweating, and working with comfort and ease he will be naturally stimulated to give greater output.

At Stewart & Lloyds, Halesowen, a large steel tube drawing factory, clusters of large air ducts have been installed over the heads and to the side of the workers in front of the furnaces. The air current from these is so great that when the furnace doors are shut one feels too cold and moves away. The men are warmed by radiant energy and cooled by wind alternately as they draw the tubes from the furnaces or pause. The effect is as congenial as the sun on a breezy day coming in and out from white clouds. The output here is greater than from any other factory of like kind, and there is no industrial unrest. An enormous improvement in health and efficiency will follow the general application of a proper cooling power to the work in hand. The heat output of different classes of workers is exemplified by the following estimates:

Man.	Additional k. cal. per hour required for work.	Woman.	Additional k. cal. per hour required for work.
Tailor	44	Seamstress	6
Bookbinder	81	Typist	24
Shoemaker	90	Sewing machinist	24- 57
Carpenter	116-164	Bookbinder	38- 63
Metal worker	141	Housemaid	81-157
Painter	145	Washerwoman	124-214
Stonemason	300		
Man sawing wood	378		

How much greater is the cooling power of wind than of change of temperature in stagnant air is shown by the following:

TABLE XIX.—*Cooling power by radiation and convection in millicalories per square centimeter per second exerted on dry "kata" surface at 36.5° C.*

[The loss by radiation is assumed to be the same as in a chamber, the walls of which are at the given temperature.]

Temperature, °C.	9 meters per second, 20 miles per hour.	4 meters per second, 8.8 miles per hour.	1 meter per second. 2.2 miles per hour.	0.5 meter per second, 1.1 miles per hour.	Still air.
0	62.0	45.6	27.7	22.6	9.8
5	53.5	39.4	23.9	19.5	8.5
10	45.0	33.1	20.1	16.4	7.1
15	36.5	26.8	16.3	13.3	5.8
20	28.1	20.6	12.5	10.3	4.4
25	19.5	14.3	8.7	7.1	3.1
30	11.2	8.1	4.9	4.0	1.7
35	2.3	1.9	1.1	0.9	0.4

I have calculated that the tailor would require a dry kata cooling power of 6, the carpenter 8–10, the stonemason 15, and the man sawing wood 18 to keep him from sweating.

The "kata" can be used as an anemometer, the formula connecting temperature and wind with the cooling of the dry "kata" having been marked out in wind tunnels. The formula, as stated in my Report to the Medical Research Council on the Science of Ventilation and Open-air Treatment (Spec. Rep. Series 32 and 52 H. M. Stationery Office, London), was

$$H/\theta = 0.29 + 0.49\sqrt{v}$$

The above figures are calculated on this formula.

Renewed investigation at a low range of velocities gave the following as more correct:

$$H/\theta = 0.12 + 0.54\sqrt{v}$$

and for velocities below 0.4 meters per second

$$H/\theta = 0.165 + 0.42\sqrt{v}$$

The wet "kata" reading is found to be about 18 to 20 in rooms which do not feel close where sedentary work is being done. In warm moist spinning sheds and mines it may be as low as 10 to 12. The wet "kata" reading is of great importance when the temperature approximates to body temperature, and cooling by convection and radiation becomes greatly reduced. Evaporation from the wet "kata" depends on the vapor pressure and wind, and the latter has a very great effect. A formula has also been worked out for the wet "kata." It must be borne in mind that the "kata" indicates cooling and evaporative powers from its own surface, not from the human body. Its bulk is comparable to the body of a mouse, and is much smaller than the parts of a human body. The "kata" readings give valuable measures of cooling and evaporative powers, but not directly measures of the cooling and evaporative loss of the body. The stimulating and suggestive lines of inquiry into the relation of health to weather and atmospheric environment, opened up by Prof. E. Huntington, require to be carried out farther with attention to readings of cooling and evaporative powers.

An extensive series of observations on people sitting in ordinary clothes indoors or outdoors exposed to the wind shows that the metabolism is correlated very closely with the dry "kata" cooling power. The cheek temperature varies greatly with exposure, e. g., from say 35° C. in overwarm factories, 33° C. in factories which do not feel close, to 20° C. or even lower out of doors exposed to cold winds. The cheek temperature also has a close relation to the metabolism when people are exposed out of doors to cool conditions. Exposure to cold wind may double the metabolism of a man sitting at rest. His natural inclination is not to sit still and feel chilled, but be active and keep himself warm. It is to this impulsion to activity and raising of metabolism that open-air life largely owes its beneficial effect.

In the winter climate of North America the cold outside air when heated up becomes very dry and increased evaporative power acting on the skin indoors cools the body. There is, too, no source of intense radiant heat (a fire) in the rooms, thus high temperatures of 70° F. or more are habitual.

If the air could be moistened, lower temperatures would be found adequate as in England where a temperature of 63° F. is considered sufficient in an office heated by hot-water radiators with natural ventilation and no sensible draft, or with a plenum system.

In the Tropics there is required the building of houses so that through draft is everywhere obtained, with wide verandas (ventilated), double roofs with ventilated air space (the vents screened to keep out animals), whitened walls, fan ventilation. The clothes must be of the lightest texture and worn widely open at neck, sleeve, and knee to allow ventilation. The skin should be allowed to pigment so that a gauzy material can be worn without sunburn resulting. Sleep should be taken on roofs where convection and radiation heat losses are greatest; a mat should take the place of a mattress, a cradle over the body covered with a sheet kept wet by a

spray or drip, and a fan to cool by evaporation may be used in hot, dry weather. The diminution of protein food, which stimulates metabolism and heat production, is indicated. Monkeys fed on rice and ripe bananas stand exposure to tropical sun out of doors. The taking of vigorous outdoor exercise keeps men much fitter in the Tropics than women shut up and cooking in houses. The body weight can be diminished to six-tenths of the pre-war figure safely, according to German reports on the effect of the blockade on the civilian population. A diminution particularly of heavy weights in the Tropics is an obvious advantage, the surface exposure being thus increased in proportion to the mass of the body.

In England belief in the open or gas fire as a source of radiant warmth is justified. The moist, misty, mild weather is thus counteracted. Gas fire must replace coal fires to secure economy of coal energy and remove the pall of smoke, dirt, and destruction of vegetable life from the towns and the great loss of health and wealth these entail. The theory that chemical purity of the air is the one important thing has permitted the establishment of slum cities, underground places of business, office rooms lighted by wells, etc.

It must be realized that the carbonic acid is never increased or the oxygen reduced in crowded rooms so as to harm, to the least extent, the occupants. Moreover, after exhaustive experiments by physiologists, proof is not forthcoming of those subtle organ poisons supposed to be exhaled by human beings. Massive saliva spray infection from carriers of pathogenic germs, and the physical state of the atmosphere depressing the vitality, these are the agents which cause ill health.

The garden city provides outdoor exercise to be taken in games and gardening, and the interests natural to most men of perfecting the homestead and raising stock and plants. Rabbits and fowls yield protein food, goats yield milk, and this and the green foods secure ample supplies of essential amino acids and vitamines. The man with his eight-hour day at the factory has his leisure filled in by productive work and he and his family are kept well fed, exercised, interested, healthy, and happy. The garden city with its factories is the main solution of health troubles of civilized people. With the garden city must go discipline, through education of the young, in the simple ways of keeping fit and enjoying life.

NOTE IN REGARD TO INDOOR AND OUTDOOR HUMIDITY.

In the discussion of indoor and outdoor humidity and temperature and its relation to disease and health, found on page 504 of the MONTHLY WEATHER REVIEW for September, 1920, the following points seem to have been overlooked:

(1) The kind of indoor heat is not stated, whether steam, direct-indirect, hot air, or stove. The "common home" is usually heated by stove or by hot-air furnace. Country schools are heated by stoves. The fluctuations of temperature and humidity would be greater with such heat and would more nearly correspond to those outdoors.

(2) Practically all the indoor temperatures cited are above what has been accepted as the optimum for human health and for mental activity, viz, 65 to 68°. New York State institutions are now required to keep the temperature at this figure. The data cited would seem to indicate that the heat was by steam and the temperature intended to be kept at about 73°. It ran up as high as 89°; the lowest was 64° F.

(3) The relative humidities are correspondingly below the optimum.

(4) If the indoor temperature is kept near the optimum of 65 to 68°, the indoor relative humidity will be higher; the body will not be constantly overheated; there will be less contrast between outdoor and indoor temperature. Sweating of the room walls will be much less apt to occur when the indoor humidity is high.

(5) Movement of the air in the room is a factor that is important to comfort and health.—*John R. Weeks.*

NOTE IN REGARD TO THE PRIMARY CAUSE OF COLDS.

It would seem that the conclusions of Dr. C. M. Richter, in 1913, quoted in the MONTHLY WEATHER REVIEW for September, 1920, page 507, in regard to the primary cause of a "common cold" are not in accord with the most recent medical thought.

The expired air from the lungs is normally near the saturation point when it passes over the mucous membranes of the nose and throat, therefore saturated air, per se, can not cause a discharge from and congestion of the mucous membranes. The air commonly enters dry and passes out moist; therefore it can not be a change from dry to moist air, per se, that would cause coryza. Even the hyperesthetic membrane is accustomed to these differences.

In recent studies of ventilation the effects of breathing saturated and humid air for varying periods have been observed. Breathing warm, saturated air *while the body is immersed in it* raises the body temperature, causes discomfort, and is injurious if there is no air circulation, but has not, I believe, been shown to cause irritation and hypersecretion in the mucous membranes of the nose and throat. Similarly, experiments have shown that chilling of the body surface causes an ischemia (anæmia) of the mucous membranes of the nose and throat instead of a hyperemia as was formerly supposed.

It may be suggested in explanation of the observed greater prevalence of colds with cyclonic weather that previous dry weather has made dust which the winds have carried from the streets to our nostrils and throats, causing mechanical irritation and bacterial implantation and growth. An amplification of this phase of the subject is given by Dr. Oliver T. Osborne, professor of therapeutics at Yale University, in an excellent article on the "common cold" that appears in the Handbook of Therapy, third edition, published by the Journal of the American Medical Association.

If we define a "common cold" (acute coryza) as an inflammation and congestion of the mucous membranes of the nose and throat, then the best medical evidence is that a "common cold" is in the great majority of cases caused by bacterial invasion. If we ask what causes or allows bacterial invasion, the answer is too long, diversified, and complicated for these pages.—*John R. Weeks.*

CLIMATE AND HEALTH, WITH SPECIAL REFERENCE TO THE UNITED STATES. [1]

By ROBERT DE C. WARD.

[Presidential address before the American Meteorological Society at Chicago, Dec. 29, 1920.]

(Author's Abstract.)

In the statement of the objects of the American Meteorological Society, the relation of meteorology to the

[1] To be published partly in the *Scientific Monthly* and partly in the *Boston Medical and Surgical Journal.*

public health is given first place in the enumeration of the practical applications of our science. There is need of general cooperation between medical men and meteorologists in the investigation of many problems as yet unsolved concerning the relations of climate and health. Few medical men have a sufficient knowledge of meteorology and climatology to enable them to make the most effective use of the available meteorological data, and very few meteorologists are competent to deal with physiological and medical relations. As one step in the direction of this much-needed cooperation, far more general instruction in the principles of climatology should be given in the medical schools of the United States.

The main features of a "good" climate are considered. No "perfect" climate can be found, equally good at all seasons, or for all seasons, or for all persons, either well or ill. The well-known health resorts have, in addition to their special climatic advantages, many other assets, such as good hotels, expert physicans, outdoor diversions, and the like.

The leading health resorts of the United States are grouped under the following divisions: I. The eastern United States; II. The Rocky Mountain and Plateau; and III. The Pacific coast. Each of these subdivisions has certain essential climatic characteristics which are peculiarly important in the treatment of special diseases. Thus, in the eastern United States, the southern winter resorts are favorable for convalescents; for those suffering from nervous debility, and for diseases of the organs of respiration. Colorado, Arizona, and New Mexico offer special advantages for the open-air treatment of tuberculosis of the lungs. The southern Pacific coast, with its equability, its short rainy season and its mild winters, has been wonderfully beneficial to many invalids who need a less stimulating climate, and one of fewer marked and sudden changes, than can be found in the northeastern part of the country.

COMPARISON OF TEMPERATURE AND HUMIDITY DURING 1920, WITH THE MEAN AND THEIR RELATION TO COMFORT, AT ANACONDA, MONT.

Being the local observer for the United States Weather Bureau, I recently summarized the data for Anaconda,

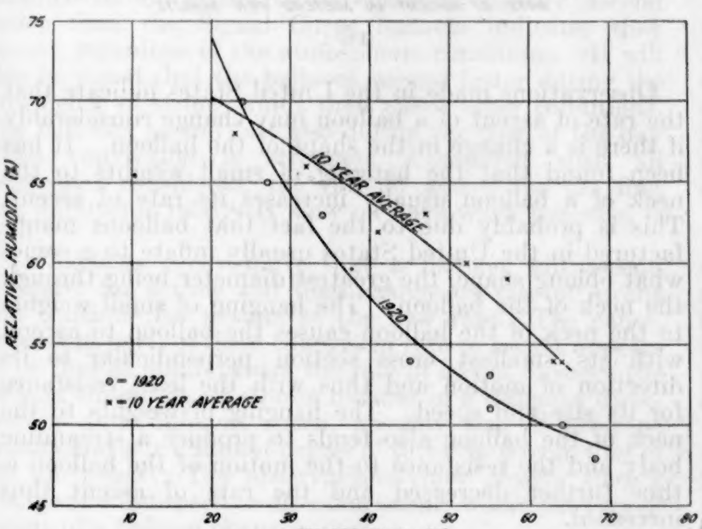


FIG. 1.—Temperature and humidity during 1920 and the mean for 10 years at Anaconda, Mont.

Mont., for 10 years past, and found that there is a very logical relation between our temperature-humidity figures during this year's mild weather season and the comfort of the season. A number of other men with whom I have talked agree that the past spring, summer, and early fall gave us the most pleasantly agreeable period that we have had for a long time, and I am convinced that the temperature-humidity relations, exhibited on the inclosed chart, largely account for this. Each point plotted for 1920 represents the average for a single month, February to September, inclusive. The form of the "10-year average" curve is very different.

The monthly figures are plotted in figure 1.

We are situated on a mountain valley, three-fourths of a mile wide, at an elevation of about 5,300 feet; and during the spring, summer, and fall commonly have breezes, of moderate velocities. Our wind records, from a recording anemometer, however, have no bearing on the comfort problem, as the instrument is placed at a high elevation above the town for special reasons.—*C. D. Demond.*

RELATION OF MALARIA TO TEMPERATURE.

[Reprinted from *The Meteorological Magazine*, London, Nov., 1920, pp. 225-226.]

A paper on the relation of temperature to the occurrence of malaria in England appears in the Journal of the Royal Army Medical Corps for August, 1920. The author, Maj. Angus Macdonald, O. B. E., R. A. M. C., has examined English temperatures records from 1763 to 1919 in conjunction with malaria prevalence, and estimated the probabilities of continuous endemicity of the disease in the past in this country and of its occurrence or recurrence in the present. It will be remembered that a disease is endemic when it continues without the importation of germ carriers from other localities.

The mean isotherm of 60° F. in the Northern Hemisphere has long been considered the northern boundary of recognized edemic malaria, and on the whole the disease increases in intensity toward the Equator. The observation of epidemics justifies the assumption that for the development of malarial infection in countries occupied by the anopheline mosquito, this mean temperature, 60° F., is necessary over at least 16 days. These mosquitoes are widespread in England. During the period 1763–1919, there has been no definite change in the temperature conditions in England; the mean of the whole differs little from means taken for casual decennia throughout. The four years 1856–1859 presented a seasonal malaria potentiality far beyond normal; on only 7 of the 50 years, 1841–1890, was the required monthly mean reached in each of the months June, July, and August, and of these, three were consecutive years, viz., 1857, 1858, and 1859. It was in these years that the last widespread and intense occurrence of malaria occurred of which we have record in this country. No other comparable record of continued high temperature existed, the nearest being 1825–26, when there was a marked occurrence of malaria, and 1808–9. Furthermore, 1860 wa a phenomenally cold year and official recognition of endemic malaria ended suddenly in that year. Greenwich records are used as representing the south of England and differing but little from those of the Fen district. Evidence of indigenous malaria north of the Humber is very rare.

The period of greatest importation of malaria carriers (i. e., persons already infected) in history was 1916–1919; the disease developed considerably in 1917–1919 in those months when the requisite thermal conditions obtained and in approximate proportion to the extent of these conditions. The outbreak was more severe in 1856–

1859, in spite of the smaller number of carriers, because of the more continuous high mean temperature of the summer months.

Elevation of temperature does not occur in England with the regularity and continuity necessary to maintain endemic malaria. When the necessary coincidence of carrier importation and high mean temperature occurs, both epidemic and endemic malaria may break out for a limited time in limited areas. Many other factors affect the disease, and the living conditions in England over 100 years ago may have been more favorable to its incidence, but the temperature factor is essential.

THE RATE OF ASCENT OF PILOT BALLOONS.

By Capt. B. J. SHERRY.

[Signal Corps, Washington, D. C., Dec. 14, 1920.]

The factors that control the rate of ascent of pilot balloons may be divided into two classes: (1) Those that relate to the kind and purity of the gas used, also to the shape, free lift, material and surface of the balloon, and (2) those that relate to the atmospheric conditions prevailing at the time of the ascension, with particular reference to temperature distribution and air movement. The air density, viscosity, etc., are considered only indirectly.

The factors included under the first class may be studied within doors. Dines, Hergesell, and others have made such studies. Some experiments along this same line have also been made by the Signal Corps, United States Army. The fact stands out, however, that in spite of much painstaking work by a number of investigators satisfactory information relative to the resistance encountered by large spheres in motion through air is not yet available.

The results of the experiments made by the Signal Corps indicate that, for the sizes of the balloons used, the air resistance to the motion of the balloons varies approximately as the 1.6 power of the speed and as the square of the diameter of the balloons. By making use of these results and comparing them with observations made by the two-theodolite method a formula was produced that gave the rates of ascent for pilot balloons that were in better agreement with observed results in the United States than any of the formulas heretofore used. An objectionable feature, however, to the experiments of the Signal Corps is that they were made by dropping weighted balloons instead of allowing gas-filled balloons to ascend.

Since the cube of the diameter of a balloon is proportional to its volume and, therefore, approximately proportional to its total lift, and the free lift of a balloon, ascending at a uniform rate is equal to the air resistance of the balloon, the terms "total lift" and "free lift" are used in the formulas instead of the cube of the diameter and the air resistance, respectively. Formulas for the rate of ascent of balloons are:

Signal Corps	Dines.	Rouch.	Hergesell.
$V=K\left(\frac{l}{L^{\frac{2}{3}}}\right)^{\frac{5}{8}}$	$V=K_1\frac{l^{\frac{1}{2}}}{L^{\frac{1}{3}}}$	$V=K_2\frac{l}{L^{\frac{2}{3}}}$	$V=f\left(\frac{l}{L^{\frac{2}{3}}-0.8L^{\frac{1}{3}}}\right)$

Where V is the rate of ascent; K, K_1, and K_2 are constants; 1 is the free lift, and L is the total lift of the balloons. The latest constant published for the Dines's formula is 84; for the Rouch formula 42. The value of f in the Hergesell formula is not given but a chart has been published showing the rates of ascent of balloons of various weights and free lifts. The Signal Corps, at first, adopted a value of 71 for the constant of the Signal Corps formula. This constant was, at the time, actually computed to be somewhat greater than 71. Additional observations indicate that a constant of 72 fits the data in hand somewhat better and has, therefore, been used in the latest work.

A comparison of these formulas for balloons weighing 50 grams with free lifts varying from 0 to 300 grams is shown graphically in figure 1.

It is a more difficult matter than it is ordinarily supposed to be to compare the rates of ascent as given by the formulas with the actual rates as determined in the free air by the two theodolite method.

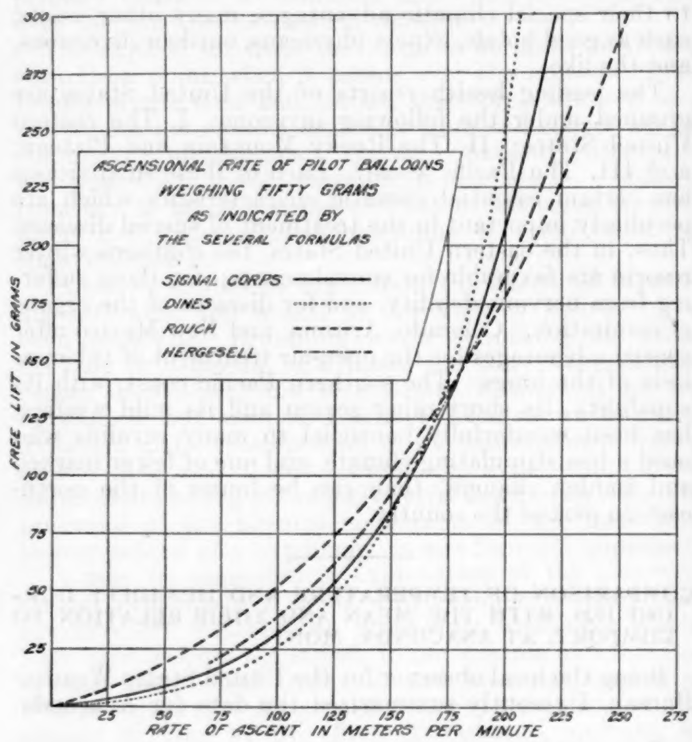


FIG 1.

Observations made in the United States indicate that the rate of ascent of a balloon may change considerably if there is a change in the shape of the balloon. It has been found that the hanging of small weights to the neck of a balloon usually increases its rate of ascent. This is probably due to the fact that balloons manufactured in the United States usually inflate to a somewhat oblong shape, the greatest diameter being through the neck of the balloon. The hanging of small weights to the neck of the balloon causes the balloon to ascend with its smallest cross section perpendicular to its direction of motion and thus with the least resistance for its size and speed. The hanging of weights to the neck of the balloon also tends to produce a streamline body and the resistance to the motion of the balloon is thus further decreased and the rate of ascent thus increased.

It was also found that the rate of ascent was further increased if the balloon was fastened into the large end of a paper cone. The balloon then ascended with the inverted cone hanging downward, thus holding the smallest cross-section area of the balloon perpendicular to its direction of motion and at the same time pro-

ducing a body that was approximately streamline. It is, therefore, evident that the distortion of the shape of a balloon will affect its rate of ascent, and few balloons remain perfectly spherical during inflation or during an ascension.

The accompanying table shows how the rate of ascent of pilot balloons varies with atmospheric conditions and with the different hours of the day. The rates of ascent for 165 balloon ascensions made at various stations are considered. These ascensions were selected from about 300 made with more than ordinary care. Ascensions have not been considered where there was reason to question the accuracy of the data and all of the ascensions used were each observed for more than 10 minutes, observations of the balloon's positions being made every minute during the ascensions. The average difference of observed altitudes at the end of the periods indicated in minutes from those computed by the Signal Corps formula is given in percentage of the formula rate. This method is used because it enables one to compare more readily ascensions made with balloons differing slightly in weight and free lift. Figures preceeded by the minus sign mean that the observed rate was less and figures with plus signs before them mean that the observed rate was greater than the formula rate.

TABLE 1.—*Comparison of observed altitudes reached with computed altitudes at end of stated periods expressed in minutes.*

Atmospheric conditions.	1	2	3	4	5	10	15	20	Number of ascensions.
Strong winds (more than 10 m. p. s., all altitudes)	+32	+24	+26	+28	+27	+13	+8	.....	10
Noon to 3 p. m.	+29	+22	+21	+18	+16	+10	+7	+5	40
Winds increasing with altitude (at least 10 m. p. s. increase)	+26	+21	+21	+19	+16	+12	+8	+8	42
Clear days	+21	+17	+15	+13	+11	+8	+6	+2	23
Not more than 5 m. p. s. increase in wind speed with altitude	+25	+9	+8	+6	+6	+2	+1	+1	39
Before 9 a. m.	+22	+13	+8	+6	+5	+3	+2	+2	35
After 3.30 p. m.	+18	+12	+11	+10	+10	+7	+4	.....	18
Cloudy days (5/10 to 10/10 low clouds)	+22	+6	+8	+9	+9	+4	.....	.....	17
Wind not more than 6 m. p. s. at any altitude reached by balloons	+17	+9	+5	+2	+3	−1	−1	−1	14

It will be seen in the table that during the first five minutes of an ascension the balloons usually ascend faster than the Signal Corps formula indicates they should, regardless of the atmospheric conditions. It will also be noted that the balloons ascend faster during the prevalence of strong winds than under other conditions. The balloons ascend fast also during the part of the day when convection is strongest. Compared with all ascensions considered, the rate of ascent for the first five minutes is relatively slow on days when the wind is light.

It happens occasionally that a balloon will ascend regularly for a time and then change its rate of ascent and continue for a time at the new rate. The cause, at least in part, of these changes in rate of ascent appears to be that at points where the rate of ascent changes the balloon enters an air stream moving in a different direction or at a different speed, possibly also of different density and of a different degree of turbulence from that of the air below. The observations show clearly that a change of wind speed or direction occurs where the rate of ascent of a balloon changes.

From the data in the table, one is inclined to attribute most of the increased rate of ascent near the ground to turbulence of the air, inasmuch as days upon which the greatest air movement takes place, the balloons ascend at the greatest speed. Ascensions made when there were 5/10 to 8/10 cumulus clouds present did not show an excessive rate of ascent for the first five minutes, but on the contrary showed about the same rate as that indicated in the table for cloudy days. It is probable, however, that there is greater turbulence near the ground on clear days than on days when cumulus clouds are present. The table indicates that the effect of weather conditions, that is wind and insolation, is confined mostly to the lower levels.

An effort has been made to check the accuracy of the Signal Corps formula. It is obvious that if one uses a formula that assumes a constant rate of ascent it is impracticable to take into account the excess rate of ascent in the lower air levels. If the formula is based on the rate of ascent in relatively still air it is probable that it will agree fairly well with the rate of ascent as observed in the upper air levels, but will give rates too slow for the lower levels and consequently all the altitudes computed from such a formula under average free air conditions, will be somewhat low.

The following table shows the average difference of actual altitudes, at the end of periods indicated in minutes, from those computed by the Signal Corps formula for balloons of various free lifts. This difference is expressed in percentage of the formula rate.

TABLE 2.—*Comparison of observed altitudes reached with computed altitudes at end of stated periods expressed in minutes.*

Free lift in grams.	1	2	3	4	5	10	15	20	25	30	35	40	Number of ascensions.
20	− 9	+ 4	+ 6	+ 3	+ 3	+ 4	+ 9	.....	.....	.....	.....	.....	7
101–125	+16	+ 5	+ 5	+ 4	+ 5	+ 1	.....	.....	.....	.....	.....	.....	19
126–150	+17	+11	+10	+ 9	+ 9	+ 6	+ 1	.....	.....	.....	.....	.....	26
151–175	+ 8	− 2	+ 4	+ 5	+ 3	+ 2	+ 1	.....	.....	.....	.....	.....	9
176–200	+23	+19	+16	+13	+12	+ 6	+ 2	+ 2	0	+ 2	+ 2	.....	19
201–250	+38	+25	+20	+18	+14	+ 7	+ 7	+ 6	.....	.....	.....	.....	16
251–300	+26	+21	+18	+15	+ 9	+11	+ 6	+ 5	+ 5	+ 4	+ 2	.....	28
301–350	+31	+21	+18	+17	+14	+ 9	+ 8	+ 5	+ 3	.....	.....	.....	22
351–400	+42	+19	+12	+11	+11	+ 4	+ 2	+ 3	+ 4	.....	.....	.....	10
401–500	+11	+10	+ 9	+ 8	+ 8	+ 8	+ 3	.....	.....	.....	.....	.....	3
20–500	+23	+16	+14	+12	+10	+ 7	+ 4	+ 4	+ 2	+ 2	+ 3	+ 2	159

It is probable that no entirely satisfactory formula for the rate of ascent of pilot balloons will be produced. Near the surface of the earth the rate of apparently similar balloons will sometimes differ as much as fifty per cent and the balloons usually ascend faster than any of the formulas indicate they should. They do not appear to ascend with a uniform rate but by a series of short spurts.

After the balloons reach an altitude of approximately 1,000 meters the rates of ascent are usually much more uniform and there is better agreement in the observed rates with the rates indicated by the formulas. There is, however, so much irregularity in the behavior of the balloons in free air that it is not safe to give very much weight to any individual ascension made with one theodolite.

When great accuracy is desired observations should be made with two theodolites, if practicable, and especially is this true when the observations are confined to altitudes less than 2,000 meters above the ground. There are, however, very practical reasons why it is not always possible to use two theodolites and, therefore, a method by which observations may be made with one theodolite is necessary.

To obtain the highest degree of accuracy in pilot balloon work it is believed that a standard rate of ascent should be adopted for both one and two theodolite work. All balloons used should be as near the same weight and shape as it is practicable to obtain. They should be inflated so as to cause them to ascend at the standard rate. A balloon weighing 30 grams inflated so as to give it a free lift of 132 grams will, it is believed, be found to be a convenient combination to use. Such a balloon should ascend at the rate of approximately 183 meters (600 feet) per minute. The use of balloons of the same weight and the same free lift has the effect of eliminating some of the possible sources of error made in computing the results of the ascensions. Observers making two-theodolite observations will become familiar with the conditions that produce variations from the expected rate of ascent of the balloons and it is believed that ultimately desirable data on this problem may be collected. Increasing considerably the free lift of a balloon above 132 grams does not increase the rate of ascent sufficiently to justify the additional expense involved in securing larger balloons.

To compensate for the increase of rate in the lower levels, certain corrections may be introduced in the computations of the altitude of the balloon during the first five minutes of the ascent. It has been found that for balloon ascensions made in the United States the computed altitudes of the balloons agree best with the actual altitudes if the rate of ascent as indicated by the Signal Corps formula be increased by 20 per cent for the first minute of the ascension, 10 per cent for the second and third minutes, and 5 per cent for the fourth and fifth minutes, respectively. A long series of observations will probably indicate that an individual series of corrections should be used for each station, and, as Table 1 indicates, these corrections vary for the different hours of the day and for the different weather conditions. However, it is evident from an examination of the data in Tables 1 and 2 and it is shown also in Table 3 that the introduction of these corrections for the first five minutes of the ascension improves the accuracy of one theodolite observation.

Table 3 shows the agreement of one-theodolite observations with two-theodolite observations with and without the corrections named above.

TABLE 3.—*Number of one-theodolite observations.*

	Within 2 per cent.	Within 5 per cent.	Within 10 per cent.	Within 25 per cent.	Within 50 per cent.	In excess of 50 per cent.	Number of observations.
Without corrections	74	178	324	560	686	18	704
With corrections	92	212	389	646	700	4	704

Table 4 indicates the agreement of one-theodolite observations with two-theodolite observations and, therefore, the degree of accuracy that may be expected from one-theodolite observations.

TABLE 4.—*Showing how single-theodolite observations agree with double-theodolite observations, made at four stations.*

At end of minutes.	Within 2 per cent.	Within 5 per cent.	Within 10 per cent.	Within 25 per cent.	Within 50 per cent.	More than 50 per cent difference.	Number of observations.
1	12	30	62	118	146	4	150
2	7	36	71	136	157	4	161
3	19	39	79	144	159	4	163
4	17	44	88	140	160	2	162
5	18	49	90	145	162	1	163
10	28	68	113	152	158	0	158
15	18	54	86	105	106	0	106
20	24	42	56	62	62	0	62
25	13	30	41	46	46	0	46
30	11	22	30	30	30	0	30
35	9	15	20	20	20	0	20
40	3	4	7	8	8	0	8
Total	179	433	743	1,106	1,214	15	1,229

In preparing the above tables it was assumed that observations made with two theodolites were correct, and where the one theodolite computations gave different results it was assumed that the one theodolite method was in error. It is recognized that this assumption may be questioned. However, in several cases when three theodolites were used, altitudes computed from the three base lines were in very good agreement, usually within 4 per cent.

A number of ascensions were made with three to five balloons, each of the same free lift, tied together. The results are not conclusive, but these groups of balloons appeared to ascend at a somewhat more nearly constant rate and at about the same rate as the average rate of a number of individual balloons of the same free lift.

SOME RECENT PAPERS ON THE RATE OF ASCENT OF PILOT BALLOONS.

(Abstract and discussion.)

By W. R. GREGG.

In 1917 R. Wenger [1] advanced the theory that variations from average rates of ascent of pilot balloons are caused by turbulence of the air, this turbulence being due to various factors, including topographic irregularities, insolation effects, and marked changes in wind direction or speed as increasing altitudes are reached. As a corollary he states that the observed variations in rates of ascent can not be accepted as indicating the presence of ascending or descending currents in the atmosphere, but rather that they constitute a direct measurement of the degree of turbulence therein. This view is quite at variance with that commonly held before Wenger's paper was published.

Recently there have appeared in *Nature* two notes in which issue is taken with Wenger's conclusions. In the first [2] Van Bemmelen presents results based upon three very complete series of observations at Batavia, Bandung, and on a small coral island in the Java Sea. Insolation was very active at the first two places, but negligible at the third. The results show at the land stations a marked increase in ascent in the first kilometer during the daytime, this increase being greatest between noon and 6 p. m., and no increase whatever at night; at the small island station there was no variation either day or night. Van Bemmelen concludes, therefore, that variations are due almost entirely to vertical currents, more especially since in his observations there was rarely found a velocity as high as 15 m. p. s., above which, according to Wenger, the effects of turbulence become most pronounced. [Wenger states that a *new* turbulent state

[1] Die Steiggeschwindigkeit der Gummiballone und die Turbulenz in der Atmosphäre. Annalen der Hydrographie und Maritimen Meteorologie, 1917, 45: 121-137.

[2] High Rates of Ascent of Pilot Balloons, *Nature* (London), June 17, 1920, pp. 485-486; abstr. in *Sci. Abs.*, Dec. 30, 1920, pp. 614-615.

enters at these high velocities. This, however, is only one of several conditions causing turbulence.—W. R. G.]

In the second note referred to,[3] Mr. J. S. Dines compares Van Bemmelen's results with those obtained in a series of observations in the Scilly Islands [4] and arrives at the same conclusion. He states that the islands are so small that no convection effects would be expected, but that, owing to the rocky and hilly nature of these islands, considerable turbulence during strong winds *would* be expected. Nevertheless, the averages show little variation in the rate of ascent with altitude, the rate being, if anything, slightly less below than above 1 kilometer. It should be noted, however, that turbulence due to the islands would not extend to any great height, since they cover only a small area and do not rise above 40 or 50 meters. In the original publication referred to [4] the average rates of ascent are given for 5 minute periods, all observations being included. For the first 5 minutes, the rate is 161 m. p. m., but if we consider the first and second minutes only we find that the rates are higher than the average, viz, 164 and 168, respectively. Moreover, 7 of the ascents, viz, Nos. 4, 18, 19, 24, 31, 32, and 33, were made under conditions of increasing wind velocity with altitude reaching approximately 15 m. p. s. during the first 5 minutes of ascent. Five of the cases cited show a rate of ascent considerably above the average in the first 2 minutes; one shows nearly the average rate, and one, a rate somewhat below the average. The mean values for the 7 cases are 178 in the first minute, 181 in the second, and 167, 153, and 157 in the third, fourth, and fifth minutes, respectively. The mean for the entire 5 minutes is 167. Averages based on so small a number of observations are not, of course, conclusive, yet the evidence seems to point to the existence of turbulence in the lower levels and a *resulting increase in rates of ascent of the balloons.*

Of considerable interest in this general connection is a recent report of pilot balloon observations at Butlers Cross, Salisbury Plain.[5] The author, Mr. Batty, has used 225 ascents in his analysis and has classified them according to time of day, amount of cloud, surface wind force, and gradient wind direction. His conclusions may be summarized as follows:

1. The average rate of ascent for all observations is greatest in the first minute, decreases during the next four minutes, and remains practically constant thereafter.
2. The rate of ascent is greatest at about noon.
3. It increases somewhat with increasing cloudiness.
4. *It is greater in strong than in light winds.*
5. "*In cases where the surface wind was changing considerably during an ascent there were large variations in the rates of ascent, especially between 1,000 and 2,000 feet*" (*300 to 600 m.*).
6. "*Gusty surface winds produce large variations in the rate of ascent of pilot balloons especially in the first 1,500 feet*" (*450 m.*).

The last three conclusions strongly support Wenger's view that turbulence, induced by strong winds or by sharp changes in wind direction or velocity, is responsible for much of the observed variation in the ascensional rates of balloons. At the same time conclusion 2 shows clearly that convection likewise has an appreciable effect on rates of ascent. But is not convection merely one of the many forms of turbulence? Undoubtedly so. Unfortunately, the idea has become rather general that convection means air in more or less uniform vertical motion. Instead, the motion is very uneven and unsteady—in no sense regular for any great vertical distance. The balloon, following the line of least resistance, goes from one vertical gust into the next higher one. This is shown by its more active darting, stair-step like motion—a phenomenon familiar to every balloon observer—when convection is active. Hence it can not be assumed that observed variations from an average rate of ascent indicate the existence of uniform vertical movement in the atmosphere.

The paper by Capt. Sherry shows very conclusively that turbulence due to winds is more effective than that due to insolation in producing variations in the ascensional rates of balloons. By referring to Table 1 in that paper we see that departures are greatest when strong winds prevail, and that they are nearly as large when winds rapidly increase with altitude; also, when convection is presumably active. When winds are light and increase but slightly with altitude, there is comparatively little increase in rate of ascent, except during the first minute.

The results given by the authors of the papers thus briefly reviewed are really not contradictory at all. They all show that the rate of ascent is higher than the average when the air through which the balloons rise is in a state of turbulence. This turbulence may be due to unequal heating of adjacent masses of air, to topographic irregularities, to high wind speeds or to different wind directions or speeds, or both, of adjoining layers.

Aside from the additional light that it throws on this subject, Capt. Sherry's paper is of special interest and importance in that it shows that the value of K in the Signal Corps formula is not materially altered by the additional data considered. (See fourth paragraph in Capt. Sherry's paper.) The original value, 71, was adopted in 1918 and has been in use since then in this country. It was based upon about 1,000 observations.[6] In the present study 165 additional observations, carefully made at several stations operated by the United States Signal Corps and the United States Weather Bureau, have been included and the resultant value of the constant is found to be 72. (NOTE.—In reality the difference is slightly less than that indicated, the original value being 71.1 and the new one 71.8.) The constant 72 will be used in this country beginning April 1, 1921. We shall also apply the additive corrections, referred to in the latter part of Capt. Sherry's paper. These are, as there given, 20 per cent for the first minute, 10 for the second and third minutes, and 5 for the fourth and fifth minutes. Without these it is found, in double theodolite observations, that the actual values nearly all lie on one side of the values computed from the formula; by introducing those corrections the results will on the average be in close agreement. Of interest in this connection is the following note by Capt. Sherry, written after the completion of his paper:

Mr. Batty (see footnote 5) used balloons weighing from 20 to 30 grams, the former with 62 grams free lift and the latter with 72 grams free lift. Balloons weighing between these amounts were filled proportionately. The Signal Corps formula indicates that the rate of ascent of a balloon weighing 20 grams and having a free lift of 62 grams will be 151.4 m. p. m.; for a balloon weighing 30 grams with a free lift of 72 grams the rate of ascent will be 151.8 m. p. m. The following is a comparison of the observed rate of ascent of Mr. Batty's balloons

[3] The Rate of Ascent of Pilot Balloons, *Nature* (London), July 8, 1920, p. 58.
[4] Cave, Capt. C. J. P., and Dines, J. S. Soundings with Pilot Balloons in the Isles of Scilly, November and December, 1911. Meteorological Office. Geophysical Memoirs No. 14, London, 1920. M. O. 2204.
[5] Batty, R. P. An analysis of the rate of ascent of pilot balloons at Butlers Cross, Salisbury Plain. Meteorological Office. Professional Notes No. 12. London, 1920. M. O. 240b.
[6] Sherry, Capt. B. J., and Waterman, Lieut. A. T. The Military Meteorological Service in the United States during the War. MONTHLY WEATHER REVIEW, April, 1919, p. 218.

and the rate indicated by the Signal Corps formula if the constant of 72 is adopted and the additions are made to the first five minutes:

Minute.	Mr. Batty's observed rate (m. p. m.).	Signal Corps rate (m. p. m.).
1	181	181.9
2	163	166.9
3	164	166.9
4	159	159.3
5	157	159.3
Mean from 5 to 10 minutes	153.2	151.6

The agreement in this table is remarkably close, and strongly confirms the accuracy of the newly determined constant, as well as the necessity of introducing additive corrections during the first five minutes.

A REPORT ON TWO PILOT-BALLOON ASCENTS MADE AT SHOEBURYNESS.[1]

By N. K. JOHNSON.

(Review reprinted from *The Meteorological Magazine*, London, Dec., 1920., p. 247.)

In the two ascents to which this note is devoted, the pilot balloons were followed with two theodolites and also with a range finder. It so happened that in each case the balloon developed a defect after reaching 25,000 or 30,000 feet; the first dropped rather quickly, the second very slowly. The usual assumption of the single-theodolite method, that the rate of ascent was uniform, would have led to entirely false results, the wind being credited with speed of 100 feet per second at 60,000 feet.

The principal moral of the paper is that when information as to air currents at considerable heights is derived from the one-theodolite method it must be used with the greatest caution; it also brings out how much is to be learned concerning the structure of the atmosphere by the more elaborate two-theodolite method.

VISIBILITY OF PILOT BALLOONS.

By NELSON K. JOHNSON.

[Abstracted from the Meteorological Magazine, December, 1920. Vol. 55, pp. 249-251.]

In order to determine the most suitable color for pilot balloons under various atmospheric conditions, four ascents were made at Shoeburyness, two differently-colored balloons, tied together with about 20 feet of thread, being used in each ascent. In each of the first three cases a red and a white balloon were used, blue having already been found unsatisfactory except against a dense white background. In the fourth ascent a plain white balloon and another white one coated with aluminum paint were used. This treatment was not effective, because the paint dried a drab gray without any metallic luster. The suggestion is made, however, that if pilot balloons can be coated in the same manner as are kite balloons, both their opacity and their reflecting power would be increased. In the three ascents with red and white balloons it was found that the white ones are best in sunshine because of their greater reflecting power, and the red in cloudy weather because of their greater opacity.

The author summarizes his results as follows:

"(1) Against a background of continuous, dense white cloud either red or blue should be used.

"(2) If the sky contains slight cirrus or haze, red is the correct color to employ.

"(3) On occasions on which the sky is cloudless and of a deep blue color, a white balloon should be selected."—*W. R. G.*

VERTICAL CURRENT DETECTED BY COMPARING CLOUD MOTION WITH APPARENT SPEED OF PILOT BALLOON.

By JOSEPH LESHAN.

[Weather Bureau, Washington, D. C., Dec. 22, 1920.]

SYNOPSIS.

The pilot balloon ascension made at Washington, D. C., on the afternoon of November 23, 1920, showed a rapid rise in velocity up to the 800-meter level, and an almost equally rapid decline thereafter to the 1,800-meter level, when the balloon entered a roll of strato-cumulus cloud. The appearance of the clouds and a nephoscope observation made at that time seem to show that the balloon gained about 100 meters during the last minute of ascension over the assumed rate of ascent, and that the velocity during the last minute should be corrected from 6.2 to 13.3 meters per second.

A comparison of the altitude-velocity curve for this ascension (the heavy line in the figure) with other altitude-velocity curves for ascensions in the vicinity taken within eight hours, shows that all but one of the

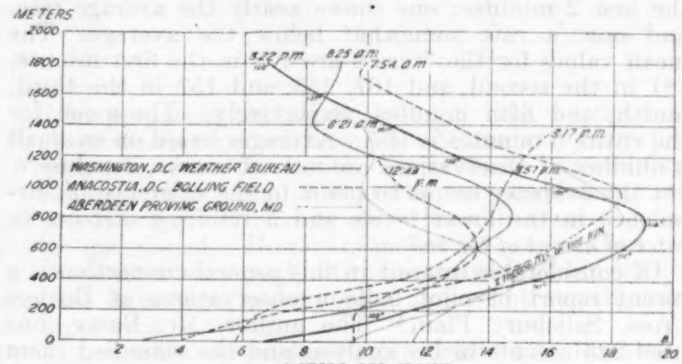


FIG. 1.—Altitude-velocity graphs for pilot balloon observations, Nov. 23, 1920. Wind directions at Washington are indicated at every 200 meters (0°=S., 90°=W.).

curves have approximately the same general characteristics except that none of them reaches as high a velocity at its maximum, nor does any of them reach as low a velocity at its minimum.

The reason for the peculiar features of the curve in question might be explained by the supposition that the balloon was in a downward current of air up to about the 800-meter level, and in an upward current during the latter part of the flight. Such currents in a single theodolite system of observation would give higher and lower computed velocities respectively.

The appearance of the lowest strato-cumulus cloud-layer at the time of observation would tend to bear out this supposition, as the clouds were in bands lying approximately northeast-southwest, and were probably formed on the crests of an air wave moving approximately from the northwest. It can be easily seen that with the balloon in the downward current of the wave the angle would be depressed and give a greater computed velocity, and conversely with the balloon in the ascending portion of the wave.

Nephoscope readings at the time of the observation indicated that the cloud which the balloon entered was moving at the rate of 7 meters per second for every thousand meters of elevation. While it is not certain that

[1] *Professional Notes, No. 13.* Brit. Meteorological Office publication.

the cloud which the balloon entered was the same as that observed in the nephoscope, and while it is not certain that the cloud entered was part of the lowest layer of strato-cumulus, the circumstances seem to justify the assumption that the nephoscope observation is applicable to the place where the balloon disappeared. In the first place the direction of motion of the cloud as observed was from 122° and that of the balloon during the last minute of flight was from 120°. Above this lowest (?) series of strato-cumulus bands were two others; the next higher (?) one was from 130 to 135° at a speed of 5.9 to 6.4 m/s for each kilometer of elevation, and the highest (?) was from 130° at a speed of 3.7 m/s for each kilometer of elevation. It was estimated at the time that the highest layer was at about 3 kilometers.

Assuming that the balloon entered the lowest layer of strato-cumulus, which were moving at the rate of 7 m/s for every thousand feet of elevation, it should have been moving at the rate of 12.6 m/s at the 1,800 meter level (the assumed altitude). If it had been moving at that rate, however, during the last minute of flight, it would have been carried out to a point 756 meters beyond where it was at the end of the eighth minute, or to a point 7,416 meters from the station. At that point, with an elevation angle of 14.3° as observed, the height of the balloon would have been 1,890 meters, which in turn would give us a velocity of 13.2 m/s, as the nephoscope readings indicated a velocity of 7 m/s for every kilometer of elevation.

Assuming a velocity of 13.2 m/s we carry the approximation one step farther, and obtain a distance out of 7,452 meters, an altitude of 1,900 meters, and a velocity of 13.3 m/s. Further approximations do not materially alter this result.

Since the balloon was so inflated as to reach 1,800 meters in 9 minutes under ordinary conditions, it appears to have gained 100 meters during the last minute of its flight on account of ascensional air currents.

A CONTRIBUTION TO THE METEOROLOGY OF THE ENGLISH CHANNEL.

By HUGH D. GRANT.

[Noted from *The Aeronautical Journal*, January, 1921, pp. 25-38.]

Owing to the notorious capriciousness of the weather of the English Channel, and to the vast dependence of transchannel navigation, both marine and aerial, upon these vagaries, this study has been made. It is an attempt to analyze the barometric disturbances which give rise to the channel weather, and the relation of the topography to the sudden changes which occur. Winds, in mid-channel and along the coast, were studied; the latter were investigated by means of pilot balloons which were filled so as to be in equilibrium in the surface air, and by this means a very good idea of the turbulence and gusts along the steep cliffs between Dover and Folkestone was obtained. Fogs, thunderstorms, gales, and squalls are also considered. It is pointed out that the number of well-equipped observatories and dense population on both sides of the channel afford unusual advantages to the investigator, owing to the large number of voluntary observers.—*C. L. M.*

PILOT-BALLOON WORK IN CANADA.

By J. PATTERSON.

[Presented before the American Meteorological Society, Chicago, Dec. 28, 1920.]

(Author's Abstract.)

The Meteorological Service of Canada in conjunction with the Air Board of Canada has established a series of pilot-balloon stations across the country. Last year stations were opened at Vancouver, British Columbia, Morley Alta (near Calgary), Camp Borton, Toronto, and Ottawa, Ontario, and Roberval (Lake St. John), Quebec. It is the intention to open stations this spring at Peace River Crossing and Fort Good Hope on the MacKenzie River. The one theodolite method was used and results plotted in the usual way.

THE MAKING OF UPPER-AIR PRESSURE MAPS FROM OBSERVED WIND VELOCITIES.[1]

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., Nov. 27, 1920.]

SYNOPSIS.

If the equation which expresses the relation between the speed of the wind and the distribution of barometric pressure be solved for the gradient in terms of the observed speed, density of the air, radius of curvature of the wind path, and latitude, it is possible to work out a fairly accurate map of the distribution of barometric pressure at upper levels. This has been done for the observations made about 8 a. m., March 27, 1920, at most of the aerological stations of the Weather Bureau and the Signal Corps. The pressures observed by kites, when used in connection with the computed gradients, give the clue to the values of the absolute pressures at the level in question. Maps of the 1, 2, and 3 kilometer levels were thus constructed.

The gradient wind.—If it is assumed, as is usually justifiable, that the effect of the friction of the earth's surface is negligible at about 500 meters above the surface, it should be possible to use observed wind velocities as a basis for determining the distribution of pressure aloft. The gradient wind equation is frequently used to determine the speed of the wind, using as a basis the sea-level distribution of pressure, but it is obvious that, by solving the equation for the gradient in terms of the speed, the density of the air, the radius of curvature of the wind path, and the latitude, an accurate upper-air map ought to result if based upon sufficient observations. Pilot-balloon observations give only wind speed and direction at various heights; and with these data alone it is possible to determine the gradient but not the absolute pressure. This deficiency may be supplied by kite observations which, when reduced, give the absolute value of the pressure at various levels. Since wind direction is an index to the direction of the isobar and, therefore, the gradient, (the latter being normal to the former) we are enabled to determine quite accurately the radius of curvature of the path. The density may be determined from kite data also. Thus we have all the necessary values to substitute in the equation.

If we take the three equations for the velocity of the gradient wind, as given by Dr. W. J. Humphreys,[2] namely:

$$(1)\ .\ .\ .\ v=\sqrt{\frac{r}{\rho}\frac{dp}{dn}+(r\omega\sin\phi)^2}-r\omega\sin\phi \text{ for cyclones;}$$

$$(2)\ .\ .\ .\ v=\frac{\frac{dp}{dn}}{2\omega\rho\sin\phi} \text{ for straight isobars;}$$

$$(3)\ .\ .\ .\ v=r\omega\sin\phi-\sqrt{(r\omega\sin\phi)^2-\frac{r}{\rho}\frac{dp}{dn}} \text{ for anticyclones,}$$

and solve them for $\frac{dp}{dn}$, we obtain, respectively,

[1] Presented before the American Meteorological Society at Chicago, Dec. 28, 1920.

[2] *The Physics of the Air*, Franklin Institute, 1920, pp. 139-140.

(4) . . . $\frac{dp}{dn}=\frac{\rho}{r}(v^2+2vr\omega \sin \phi)$ for cyclones,

(5) . . . $\frac{dp}{dn}=2v\omega\rho \sin \phi$ for straight isobars;

(6) . . . $\frac{dp}{dn}=\frac{\rho}{r}(2vr\omega \sin \phi-v^2)$ for anticyclones;

in which v is the velocity, $\frac{dp}{dn}$ is the difference in pressure per unit horizontal distance normal to the isobars $r=r_1 \sec \alpha$, where r_1 is the radius of curvature of the wind path, and α is the angular radius of the circle upon which the air is moving measured from the center of the earth; ρ is the density of the air; ω the angle through which the earth turns in a second; and ϕ is the latitude of the place.

Since the difference between r and r_1 is usually small, and, in this case, the value is only an approximation, it is possible to regard them as equal. It is noticed further that the three equations which have been solved for $\frac{dp}{dn}$ contain the term $2\omega\rho$. For a given level, this may be considered as a constant, since we may assume the value of the density constant for a given level. The value of the density used was that given by Dr. H. H. Kimball as standard.[3] The angular velocity of the earth's rotation is, of course, $\frac{2\pi}{86,164}$. These factors when multiplied together give a constant for the level in question. For it the following values of this constant have been computed:

Altitude (km.).	ρ (kg/m³).	Constant $\left(\frac{4\pi\rho}{86,164}\right)$
1	1.104	161×10^{-6}
2	0.996	145×10^{-6}
3	0.896	131×10^{-6}

The computations.—Owing to the difficulty in obtaining an accurate estimate of the radius of curvature of the wind path, and the fact that, in general, such radii are very large, it has been suggested that only the straight-isobar equation be employed in this connection. This would have the advantage of making the computation somewhat simpler. It is doubtful, however, whether this equation should be used universally in determining the pressure gradient. Reference to figure 40, page 143, in the "Physics of the Air" shows what the error would amount to in meters per second when the velocity is determined by equations (1), (2), or (3). The diagram is computed for latitude 40° and a pressure gradient of 1 millimeter of mercury per 100 kilometers. It is seen that when the radius of curvature is very large, greater than 1,200 kilometers, the agreement between equations (1) and (2) and between (3) and (2) is within 2 meters per second. With radii less than 1,200 meters, however, the discrepancy becomes rapidly larger, especially in the case of the anticyclone where, under these conditions, the radius of the critical isobar is about 600 kilometers; at this radius the difference between equations (3) and (2) amounts to slightly over 7 meters per second. Between equations (1) and (2) the difference at 600-kilometer radius is about 2 meters per second, and at 100-kilometer radius the difference amounts to about 6 meters per second. These discrepancies seem to be sufficiently large to demand the use of the cyclone and anticyclone equations where the radii are short.

The question of which equation to use in solving for the gradient was answered by inspection of the preliminary charts of wind stream lines which were sketched from the wind directions as observed. It is possible with these data to procede to the solution. The following table gives the observed data as to wind direction and speed at the 1, 2, and 3 kilometer levels from pilot balloons and kites:

TABLE 1.—*Observed wind directions, and speeds.*

Station.	1 kilometer.		2 kilometers.		3 kilometers.	
	Direction.	Speed.	Direction.	Speed.	Direction.	Speed.
		m/s.		*m/s.*		*m/s.*
Denver, Colo.			NW.	4		
Fort Sill, Okla	SSW.	27				
Ellendale	NE.	6	SSE.	5	SW.	11
Drexel	SSW.	19	SSW.	19		
Broken Arrow	SSW.	20				
Kelly Field	SSW.	7	SW.	15	WSW.	19
Madison	S.	8	SW.	12	WSW.	8
Lansing	NNW.	16	NW.	20	NW.	22
Royal Center	WNW.	8	W.	16	WNW.	16
Camp Knox	WSW.	9	W.	12	WNW.	11
Leesburg	NW.	5	NW.	3	WSW.	14
Mitchel Field	W.	14				
Aberdeen	W.	19	WNW.	17		
Washington	WNW.	21				
Camp Vail	W.	18				
Fort Monroe	W.	10	WNW.	17	WNW.	25
Camp Bragg	WNW.	9	W.	11		

In Table 2 are given the data from which it is possible to draw the isobaric maps of the upper levels. For each level the data include the value of the gradient in millibars per 100 km. horizontal distance, the distance between isobars in kilometers for pressure intervals of 2.5 millibars, the actual pressure observed with kites in millibars, and the estimated pressure at several of the kite stations, where the kites did not quite attain the desired altitude. This extrapolation was effected by use of the hypsometric formula, using the greatest altitude attained by the kite as the lower level and the desired altitude as the upper level, and using as the mean temperature of the air column that value of temperature which would have been attained at the middle of the intervening air column had the vertical gradient continued at the rate observed at the highest point in the flight. This gives a value of the pressure at the upper level which is probably very nearly correct. This operation was performed in the case of Ellendale and Broken Arrow for the 2-kilometer level, and for Ellendale, Drexel, and Broken Arrow for the 3-kilometer level.

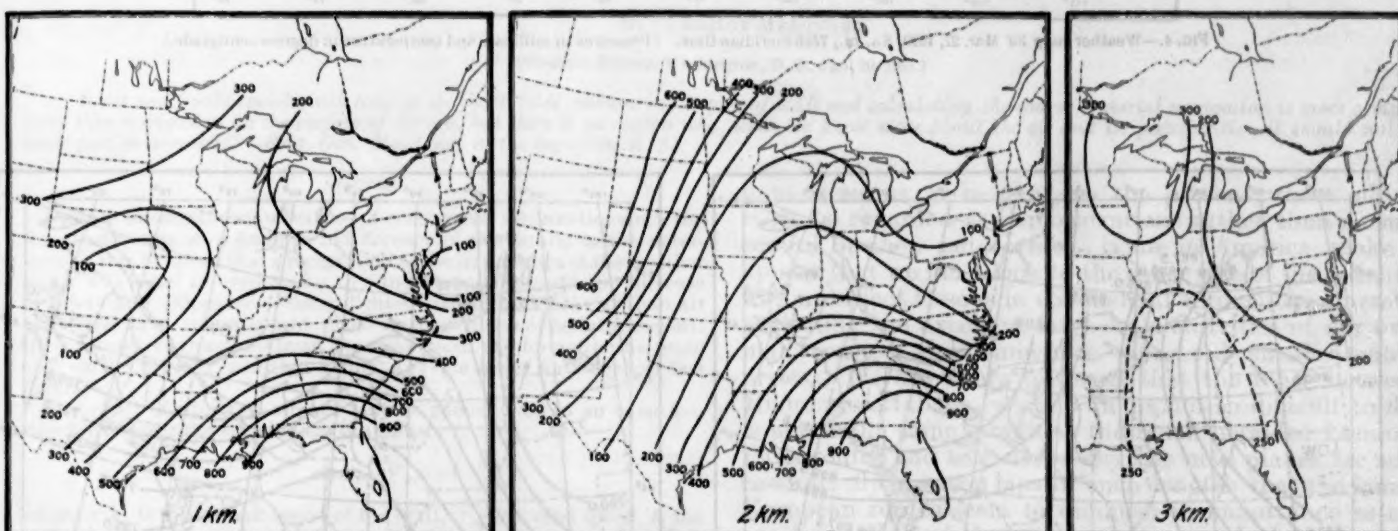
[3] Kimball, Herbert H.: On relations of atmospheric pressure, temperature, and density to altitude. MONTHLY WEATHER REVIEW, March, 1919, 47:156-158.

TABLE 2.—*Observed pressures and computed gradients.*

Station.	1 kilometer.				2 kilometers.				3 kilometers.			
	$\frac{dp}{dn}$ (mb/100 km.).	Distance between isobars (km.).	Observed pressure (mb.).	Estimated pressure (mb.).	$\frac{dp}{dn}$ (mb/100 km.).	Distance between isobars (km.).	Observed pressure (mb.).	Estimated pressure (mb.).	$\frac{dp}{dn}$ (mb/100 km.).	Distance between isobars (km.).	Observed pressure (mb.).	Estimated pressure (mb.).
Denver					0.4	641						
Fort Sill	2.5	102										
Ellendale	0.8	352	881.6		0.5	481		778.2	1.1	240		685.6
Drexel	2.8	92	883.0		2.5	102	783.8					693.[illegible]
Broken Arrow	2.0	121	893.4					793.6				702.5
Kelly Field	0.5	481			1.2	213			1.2	213		
Madison	0.9	273			1.3	192			0.7	385		
Lansing	1.3	192			2.4	105			1.3	192		
Royal Center	0.9	273	898.8		1.2	213	796.2		1.2	213	703.0	
Camp Knox	0.8	352			0.8	352			0.9	273		
Leesburg	0.3	962			0.3	962			0.9	273		
Mitchel Field	1.6	159										
Aberdeen	2.2	113			1.8	136						
Washington	2.5	102										
Camp Vail	2.1	121										
Fort Monroe	1.1	240			1.6	159			2.0	121		
Camp Bragg	0.8	352			0.8	352						

AUXILIARY CHARTS.

In order to facilitate the drawing of the maps, auxiliary charts (figs. 1, 2, and 3) were drawn. These figures show the distance between isobars in eastern United States where the interval of pressure is 2.5 mb. The lines of equal distance between isobars are drawn for every 100 kilometers from the data contained in Table 2. By means of these figures, one can tell at any point in the region in question what the distance is between the isobars.



FIGS. 1, 2, and 3.—Auxiliary maps showing distance between isobars in eastern United States at the 1, 2, and 3 kilometer levels, Mar. 27, 1920, 8 a. m., 75th meridian time.

UPPER-AIR PRESSURE MAPS.

Figure 4 shows the distribution of pressure and temperature on the morning of March 27, 1920. The isobars are for sea-level in millibars, and the isotherms are for the surface in degrees, centigrade. Figures 5, 6, and 7 show the distribution of pressure at the 1, 2, and 3 kilometer levels, respectively.

The 3-kilometer map shows the tendency for the low center to shift westward, which is what would be expected, since the inflow of cold dense air in the rear of the cyclone would tend to concentrate a great weight of air in the lower layers with a lower pressure at upper levels. The effect of the HIGH in the southeastern part of the United States, while still strong at the 2-kilometer level has disappeared at the 3-kilometer level. This is shown also by the slight winds at Leesburg up to 2 kilometers which change to strong from the WSW. at the 3-kilometer level.

In one or two cases it will be seen that the station arrow does not exactly coincide with the direction of the isobar nearest the place. This may be due to one of two reasons: either the winds were so gentle that the indicated direction was of little significance, or the legitimate smoothing of the isobar necessitated making it pass the station at an angle slightly at variance with the arrow. It should be remembered that the directions are given only in 16 compass points and for this reason such slight discrepancies can not be avoided.

It will be seen that at the 3-kilometer level the gradient as drawn in figure 3 is somewhat less than that shown in figure 7. This is believed to be justified by the fact that the estimated pressure at Ellendale is more reliable than the value of the gradient. There is no wind record at Ellendale for that elevation, hence it is fair to suppose that figure 3 is less trustworthy than the extrapolated

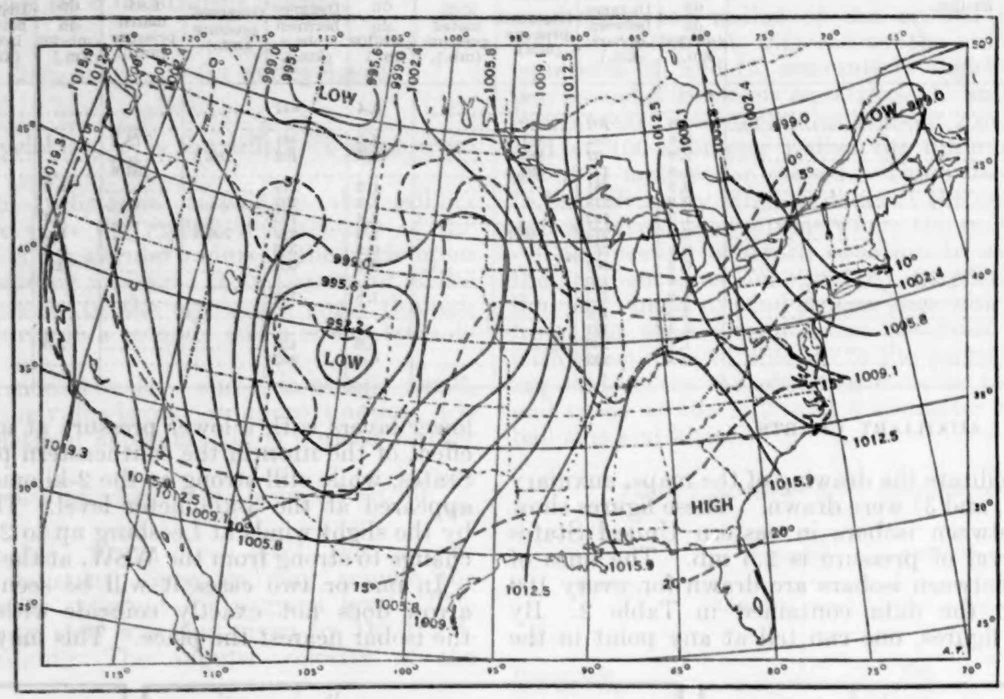


FIG. 4.—Weather map for Mar. 27, 1920, 8 a. m., 75th meridian time. (Pressures in millibars and temperature in degrees centigrade.)

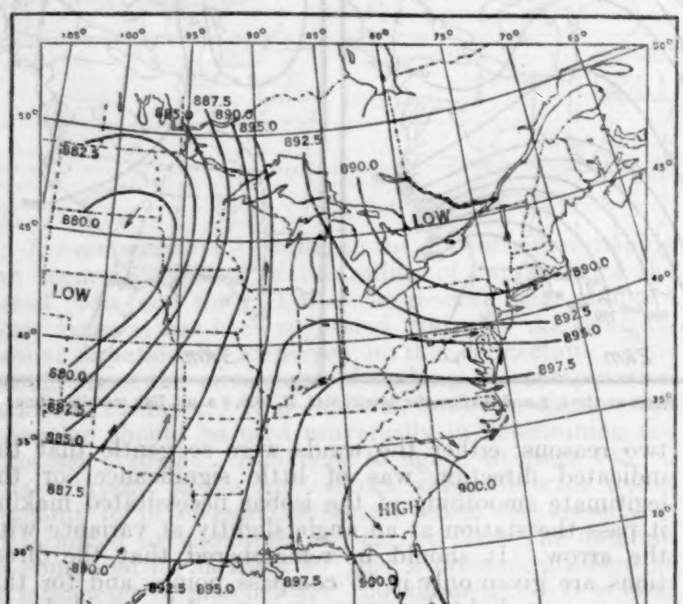


FIG. 5.—Pressure at the 1-kilometer level, in millibars, Mar. 27, 1920, 8 a. m., 75th meridian time.

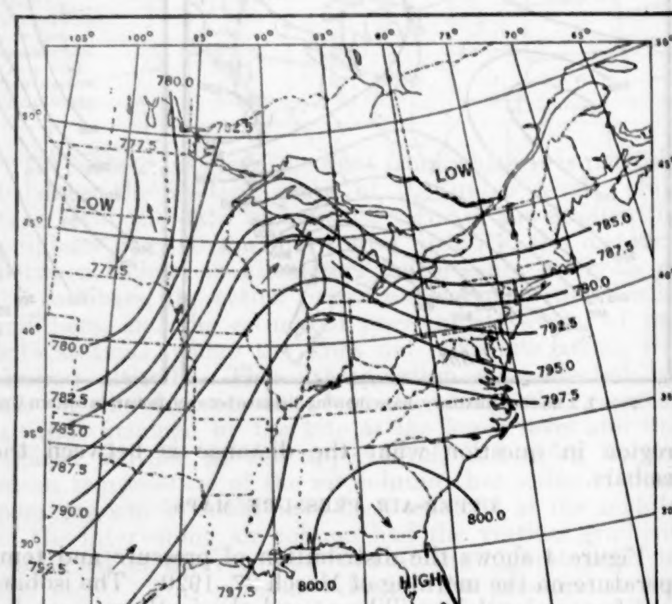


FIG. 6.—Pressure at the 2-kilometer level, in millibars, Mar. 27, 1920, 8 a. m., 75th meridian time.

pressure, and for that reason, the pressure slope has been represented somewhat steeper than the gradient uld indicate.

CONCLUSION.

This short study is an example of the application of the theory of the gradient wind. In spite of the many observational errors that may creep into pilot-balloon data, especially when obtained by the single theodolite method, there is a striking congruity in the figures obtained. It is true that at present the making of such maps by this method is impracticable, not only because of the considerable computation involved, but also because of the number of aerological stations is too small to furnish as much data as would be required. Nevertheless, the difficulties of the proposition lie more largely with external circumstances than with the scientific reasoning. We must improve our methods of forecasting for aviation, and to do it we must have first-hand knowledge of what is going on aloft—not in a desultory and fitful manner, but in a solid, consistent network of aerological stations. Those the Weather Bureau is operating at present are doing excellent work, and the assistance of the Signal Corps is extremely useful, but still this is only a beginning and expansion in the aerological work is one of the greatest needs of the Weather Bureau. Such a method of drawing charts of the upper air may prove to be useful in preparing wind charts for aviators.

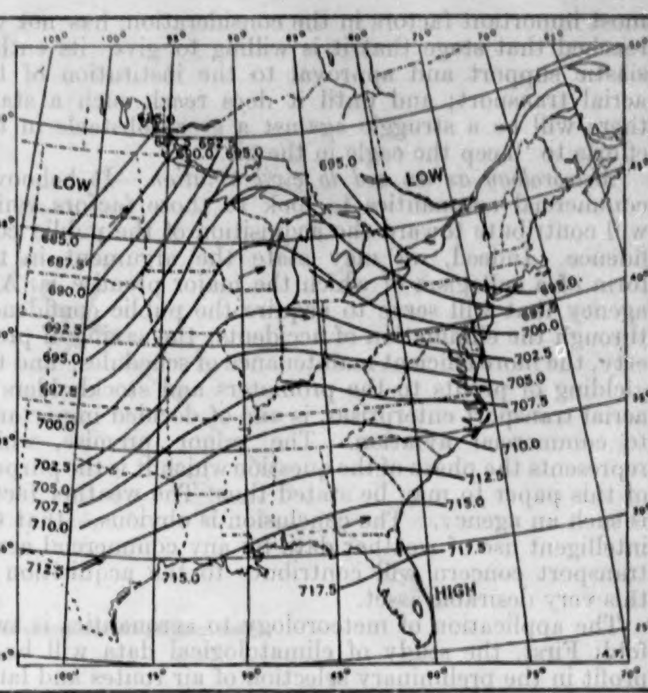


FIG. 7.—Pressure at the 3-kilometer level, in millibars, Mar. 27, 1920, 8 a. m., 75th meridian time.

THE WEATHER FACTOR IN AERONAUTICS.[1]

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., Jan. 20, 1921.]

"Scott and Cooke spend much time at the chart table, measuring angles of drift and calculating the course. Aerial navigation is more complicated than navigation on the surface of the sea, but there is no reason why, when we know more about the air and its peculiarities, it should not be made just as accurate."—Brig. Gen. Maitland, in the log of the R. 34.

SYNOPSIS.

Despite the significant advances of commercial aeronautics since the war, there remains a singular indifference of the public to the enterprise. It is believed that a recognition of the importance of the weather factor will assist in overcoming this indifference through the increase of safety and efficiency. Since lighter-than-air and heavier-than-air craft each have an important place in the scheme of aerial transport, their respective functions must be understood; the former is the probable carrier for long, non-stop flights, and the latter for the short fast flights.

The effect of winds on aircraft may be summed up in an equation, which expresses the speed along the course:

$$V = V_a \cos\theta_1 - V_w \cos\theta$$

wherein V_a is the still-air speed of the craft, V_w the wind speed, θ_1 the angle the craft must turn relative to its course to overcome the effect of drift and θ the angle between the wind direction and the course.

The experience of great European commercial aerial transport enterprises has indicated that the development of this form of transportation will naturally evolve a field for the aeronautical meteorologist, whose work will consist essentially in reducing for the benefit of his organization the detailed information for the individual pilots, a function too complex for any governmental agency to handle.

A specific example of the effect of winds on flight is given which indicates the lines along which meteorological information may be organized.

In this connection, one research problem of profound importance is that of the reduction of barometric pressure to levels in the free air. The success of this problem is largely dependent upon the amount of upper-air observations collected.

INTRODUCTION.

Civil aviation in the United States.—The trend of opinion among those who are most conversant with the results of the first years' efforts in commercial aeronautics seems to be that, to the present, these efforts must be regarded as demonstrations rather than as successful business enterprises. Some in America, make it appear that we must look to the other side of the Atlantic for our object lessons in commercial aeronautics, thereby neglecting the excellent large-scale activities of our own mail service and numerous successful smaller enterprises. We are likely to forget that the route between Miami and Habana, while perhaps not so difficult to fly, is about the same length as the much heralded London-Paris route; and that every day the mail planes are successfully flying over laps of such lengths that the famed European routes seem to diminish in importance as examples. We find that our activities are looked upon by European nations with a considerable degree of interest and our Aerial Mail regarded by Maj. Gen. Sir F. H. Sykes, comptroller general of civil aviation, as a "particularly interesting experiment."[2] There are those who point out that a lack of adequate laws is holding in leash numerous enterprises which stand ready to put into operation a large program of aerial transportation. The legal problem involved is of considerable magnitude and profound importance.[3]

Yet with all the interest and encouraging prospects of the efforts, there appears to be a singular indifference on the part of the public to commercial aeronautics. And this may be attributed in a large measure to the lack of publicity given the venture.[4] In any event, the fact must be recognized that the confidence of the public, one of the

[1] Presented, in part, before the American Meteorological Society, at Chicago, Ill., Dec. 28, 1920; and the Philosophical Society of Washington, Feb. 12, 1921.

[2] Civil aviation abroad. *U. S. Air Service*, December, 1920, pp. 24-26.

[3] Davis, Maj. W. Jefferson: Laws of the air. *U. S. Air Service*, December, 1920, pp. 17-20.

[4] Aerial mail as a promoter of commercial aeronautics. Editorial note. *Aerial Age Weekly*, Nov. 29, 1920, p. 315.

most important factors in the consideration, has not yet reached that stage that it is willing to give its enthusiastic support and approval to the institution of the aerial transport; and until it does reach such a state, there will be a struggle against a great obstacle in the efforts to "keep the eagle in the air."

Meteorology as an aid to civil aviation.—It behooves commercial aeronautics to look to those factors which will contribute toward the acquisition of the public confidence. Indeed, we may state the argument in the form of a syllogism of which the major premise is: Any agency that will serve to acquire the public confidence, through the elimination of accidents, the saving of property, the more efficient maintenance of schedules, and the yielding of profits to the promoters and stockholders in aerial transport enterprises, is one of decided importance to commercial aviation. The minor premise, which represents the phase of the question which it is the purpose of this paper to may be stated thus: The weather factor is such an agency. The conclusion is obvious,—that the intelligent use of weather data by any commercial aerial transport concern will contribute to the acquisition of this very desirable asset.

The application of meteorology to aeronautics is twofold: First, the study of climatological data will be of profit in the preliminary selection of air routes and landing fields; and, second, the consideration of the current weather conditions will be of immediate importance in the conduct of the craft in the air. The first of these applications has been discussed in an earlier paper.[5] The second will be considered here as far as it is possible to point out in a general way the use of current meteorological information.

THE FUNCTION OF DIFFERENT TYPES OF AIRCRAFT.

Speed, the chief characteristic.—To consider this question properly, it is necessary to have some appreciation of the functions of the different types of aircraft. The question has been asked, Which is the more practical in commercial aeronautics, the airplane or the dirigible? But it is generally conceded that this is hardly a legitimate question, since each type has a place to fill, which, instead of encroaching upon the domain of the other, is really supplementary to the other. Mr. G. Holt Thomas,[6] and other of the important men in the field of commercial aeronautics have pointed out that the commodity which the transport corporation has to offer is speed. If it can not supply speed—greater speed than it is possible to obtain with any other known means of surface transportation—it can not succeed.

The airplane vs. the dirigible airship.—As is well known, the airplane *does* supply speed, and much greater speed than can even be approximated by any means of surface transport. But the deficiency of the airplane is, despite the ambitious designs of the Fokkers, Capronis, or Lawsons of the commercial world, its limited carrying capacity, owing to the large weight of fuel which must be carried for long journeys. The dirigible balloon, on the other hand, has the ability to remain aloft for days at a time, and has a relatively large carrying capacity. Its limitation is speed, for, while the dirigible can travel fast, it can not greatly exceed the speed of fast trains, if it has an appreciable wind to contend with. But the fact that it can remain in the air for long periods and carry so much weight makes it appear as an efficient long distance carrier, such as might be used for transoceanic or transcontinental traffic.[7] The two types of craft do not, therefore, encroach upon each other.

The airplane is efficient for the short, high-speed transportation; the dirigible is suitable for the slower, but longer, journeys. The airplane, someone has said, will be the feeder to the dirigible. The transoceanic dirigible will be loaded from airplanes flying in from all directions to its terminals. The transcontinental dirigible will make few stops, but at each it can take aboard the gleanings of the airplane network in the vicinity of the airport. The relay method now employed in the Post Office Department is an example of the efficient use of the airplane in relatively short, fast, flights.

With this short and very general discussion of the two types of commercial craft, we may examine into the use and dissemination of data regarding current conditions and probable future conditions by a commercial aeronautic corporation. The important phenomena are, as has often been mentioned, winds and clouds. It is a self-evident fact that the aviator wants to fly at that level where he will receive the greatest assistance from the wind. But his question is, where are these favorable levels?

THE EFFECT OF WINDS ON FLIGHT.

The effect of wind components.—Before the above question is discussed, it will be well to call attention to the relations between winds and the motion of aircraft which are, for the most part, well known but perhaps not fully appreciated. Let us consider figure 1. Suppose that the direction AB represents the direction of desired flight, and its length the distance the flight of the craft in quiet air in unit time. Let a wind blowing at an angle θ to the course be represented by the vector CA. If the craft were wholly subject to the wind, as is a free-balloon, in unit time the craft would be carried to C′. If, however, the craft were trying to remain on the course AB, it would be necessary for the pilot to turn it through a certain angle which would be determined by swinging an arc of radius equal to AB with C′ as a center. Where this arc intersects the course AB at H is located the final position of the craft after unit time has elapsed. The vector AH, therefore, is the resultant of the two forces or the diagonal of the parallelogram of forces AC′HF.

It is instructive, however, to break the wind up into two components, the first, CE, parallel to the course AB, and the second, CD, perpendicular to it. Since, as was shown above, the perpendicular component CD is the cause of the turning of the craft through a certain angle θ_1, it is possible to show how much speed would be lost by the craft if the perpendicular component alone were operative. This is shown by projecting the point F on AB. In other words, the point G is the location of the craft after unit time with the wind component CD acting alone. If the craft is moved backward along its course by an amount equal to the parallel component CE, the point H is reached, as was shown above.

The effect of the perpendicular component.—The amount of the loss of speed attributable to the wind component perpendicular to the path is obviously given by the equation.

$$V_1 = V_a\ (1 - \cos \theta_1)$$

[5] Meisinger, C. LeRoy: Climatological factors governing the selection of air routes and flying fields. MONTHLY WEATHER REVIEW, September, 1920, pp. 525-527; reprinted in *Aerial Age Weekly*, Dec. 13, 1920, pp. 338-369 and 373; *Aviation and Aeronautical Engineering*, Dec. 13, 1920, pp. 423-425; and *Scientific American Monthly*, January, 1921, pp. 68-70.

[6] Aerial transport. (London), 1920, pp. 3-4, 7.

[7] Maitland, E. M.: The commercial future of airships. *U. S. Air Service*, January, 1921, pp. 22-26.

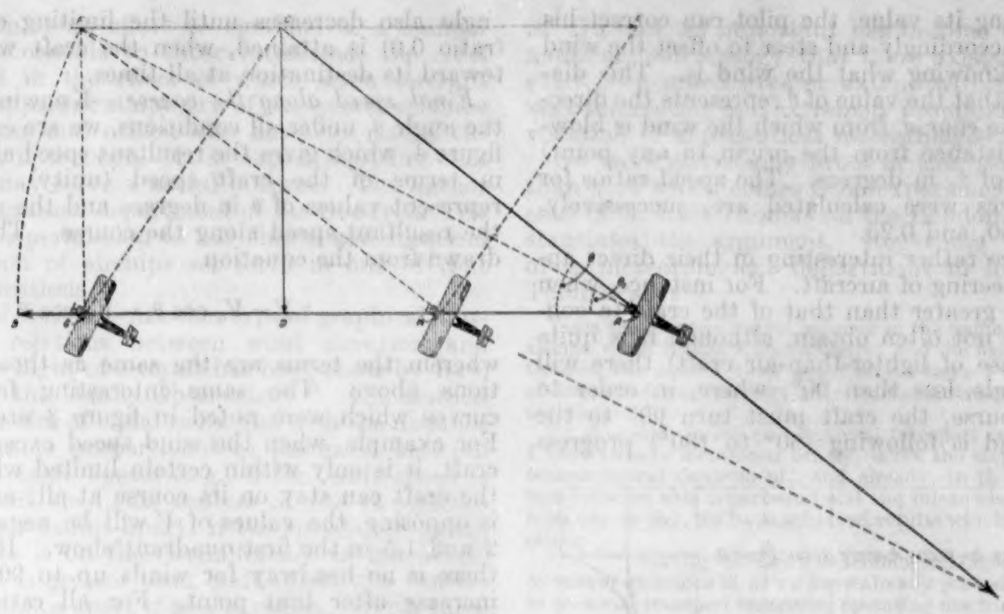


FIG. 1.—The effect of winds upon the movement of an airplane along a given course.

in which V_1 is the loss of speed, and V_a is the air speed of the craft. In order to show quantitatively what the loss of speed due to this perpendicular wind component may amount to, figure 2 has been drawn. The ordinates represent component magnitudes, the abscissae, craft speeds. The lines slightly rising to the right are drawn for each mile per hour loss. By knowing the air-speed of a given craft and the magnitude of the perpendicular component, it is possible to tell at once how much must be subtracted from the air speed to show the forward progress, neglecting the component parallel to the path. For slow craft and large wind components, this

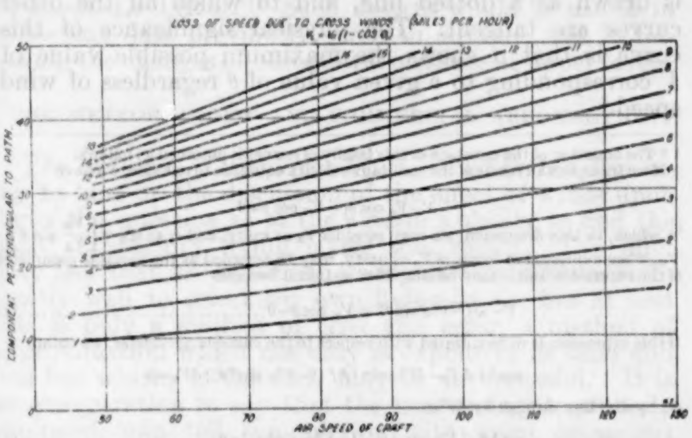


FIG. 2.—Loss of speed owing to the wind component perpendicular to the course.

may amount to 10 or more miles per hour, which would be worth considering in practice. For high speed craft, this quantity is considerably less.

The angle at which craft should be turned.—It will now be of interest to find the relation between the strength of the wind, and the angle from which it is blowing with respect to the route, under various conditions. It was shown in figure 1 and the discussion, that the angle at which the pilot must turn his craft with respect to the route is dependent upon the speed and direction of the wind and the speed of the craft. It is clear, therefore, that this angle may be given by the equation

$$\sin \theta_1 = \frac{V_w}{V_a} \sin \theta$$

or,

$$\theta_1 = \sin^{-1}\left(\frac{V_w}{V_a} \sin \theta\right)$$

where θ_1 is the angle between the craft and the course and θ is the angle between wind and course, and V_w and V_a the speeds of the winds and craft, respectively.

If this equation is solved for various values of the ratio $\frac{V_w}{V_a}$, there results a family of curves which, for the purpose in hand, may be most effectively plotted in polar coordinates. Such a diagram (fig. 3) will show the cor-

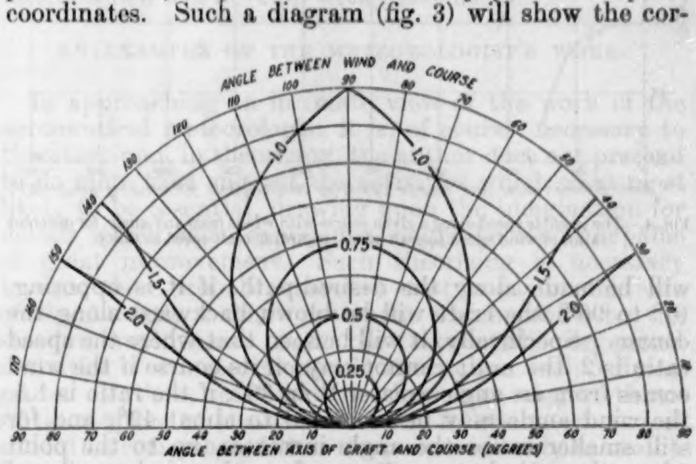


FIG. 3.—The angle a craft must turn from the desired course in order to overcome the effect of drift, for different ratios of wind speed to craft speed.

rect angle at which the craft must be steered under the various conditions. It has been said that, in issuing information of a meteorological character to the Navy fliers when the NC planes started their trans-Atlantic journey, this angle was estimated and given to them, and for it they seemed especially grateful. It is the meteorologist alone who can tell the aviator the value of this

angle; and, knowing its value, the pilot can correct his compass bearing accordingly and steer to offset the wind without actually knowing what the wind is. This diagram is so plotted that the value of θ represents the direction, relative to the course, from which the wind is blowing, and r (the distance from the origin to any point) represents values of θ_1 in degrees. The speed ratios for which these curves were calculated are, successively, 2, 1.5, 1, 0.75, 0.50, and 0.25.

These curves are rather interesting in their direct application to the steering of aircraft. For instance, when the wind speed is greater than that of the craft (a condition which does not often obtain, although it is quite possible in the case of lighter-than-air craft) there will be some wind angle, less than 90°, where, in order to remain on the course, the craft must turn 90° to the path. If the wind is following (90° to 180°) progress

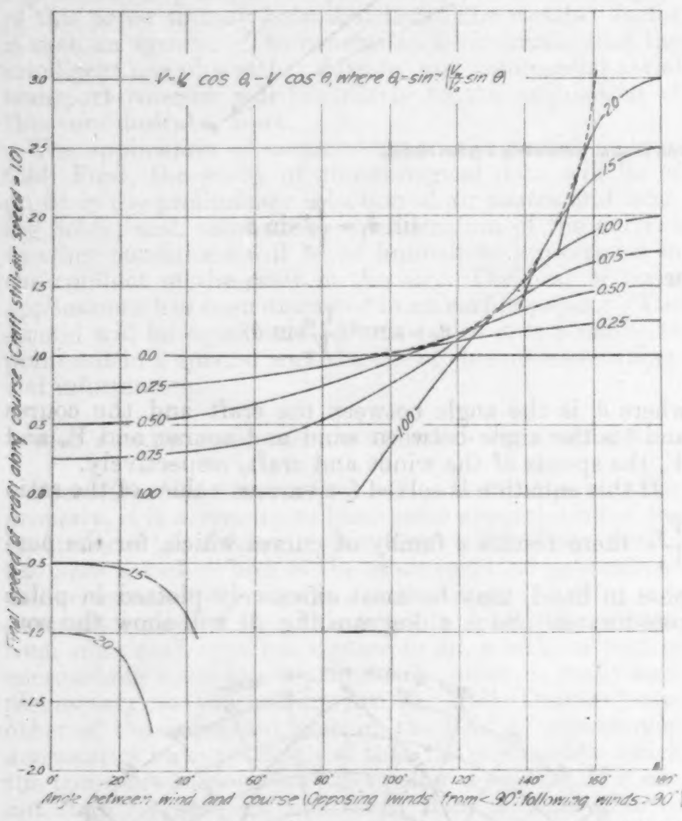


FIG. 4.—The possible speed along a given course with winds from any angle, for different ratios of wind speed to craft speed, regarding craft speed as unity.

will be made along the desired path; if it is opposing, (0° to 90°) the craft will be blown backward along the course. Specifically, it will be seen that where the speed ratio is 2, the craft cannot stay on its course if the wind comes from an angle greater than 30°; if the ratio is 1.5, the wind angle may be increased to about 42°; and for still smaller ratios the angle increases, up to the point where the ratio becomes 1, or where the wind speed and craft speed are just equal. At that point, with the wind coming from any direction less than 90°, the craft must head directly into it in order to hold its own. When the wind comes from more than 90°, it is clear that the craft will be materially aided on its course. When the craft is going faster than the wind, as is usually the case, the curves become closed and, regardless of wind direction, there is no condition where the craft must be turned as much as 90° in order to make headway on its course. As the ratio becomes smaller and smaller, the maximum angle also decreases until the limiting case of a calm (ratio 0.0) is attained, when the craft will be directed toward its destination at all times.

Final speed along the course.—Knowing the value of the angle θ_1 under all conditions, we are enabled to draw figure 4, which gives the resultant speed along the course in terms of the craft speed (unity). The abscissae represent values of θ in degrees and the ordinates V, or the resultant speed along the course. These curves are drawn from the equation

$$V = V_a \cos\theta_1 - V_w \cos\theta$$

wherein the terms are the same as those in the equations above. The same interesting features of the curves which were noted in figure 3 are obvious here. For example, when the wind speed exceeds that of the craft, it is only within certain limited wind angles that the craft can stay on its course at all; and, if the wind is opposing, the values of V will be negative, as curves 2 and 1.5 in the first quadrant show. If the ratio is 1, there is no headway for winds up to 90°, but a rapid increase after that point. For all ratios less than 1 headway can be made along the course.

Another interesting feature of the curves is the indication of the point, or wind angle, at which the craft can proceed along the course at its own still air speed. This value is given by the value of the abscissa where the curves intersect the line $V=1$. It should be remarked that only those curves having a direct physical significance in relation to the flight of craft have been plotted here; in a mathematical discussion they are incomplete. Indeed, to the equation there are two solutions, only one of which has been plotted, and, in the case where the ratio is 1, one solution is used from $\theta=0°$ to 90°, and the other from $\theta=90°$ to 180°. This remark applies also to the portion of the envelope which is drawn as a dotted line, and to which all the other curves are tangent. The physical significance of this curve is that it shows the maximum possible value of V corresponding to a given value of θ regardless of wind speed.[8]

[8] The equation of the envelope of this family of curves is obtained as follows: If we transpose all terms of the resultant velocity equation to one side, we have

$$V - V_a \cos\theta_1 + V_w \cos\theta = 0$$

in which, in this discussion, we may consider V_a as unity, and θ_1 as $\sin^{-1}\left[\frac{V_w}{V_a}\sin\theta\right]$. V_w, when expressed in terms of V_a as unity, may be regarded as the variable parameter of the expression and it may be simplified so that it becomes

$$V - \sqrt{1 - V^2_w \sin^2\theta} + V_w \cos\theta = 0 \qquad (1)$$

If this expression is differentiated with respect to the variable parameter, we obtain

$$\cos^2\theta \, d V_w - [V^2_w \sin^4\theta / (1 - V^2_w \sin^2\theta)] \, dV_w = 0$$

or, by dividing through by dV^2_w,

$$\cos^2\theta - [V^2_w \sin^4\theta / (1 - V^2_w \sin^2\theta)] = 0 \qquad (2)$$

Solving (2) for V_w, we obtain, as the solution pertinent to this problem,

$$V_w = \pm\frac{\cos\theta}{\sin\theta} \qquad (3)$$

The values of V_w for our practical purpose are always positive, so we may legitimately consider the plus sign to hold in the first quadrant, and the minus in the second; and, since the envelope will have no significance in the first quadrant, the plus value can be ruled out of this discussion, with the provision that must lie in the second quadrant. Bearing this in mind, we may thus eliminate V_w by substituting (3) in (1), thus obtaining

$$V - \sqrt{1 - \cos^2\theta} - (\cos^2\theta / \sin\theta) = 0$$

and, solving for V,

$$V = (\sin^2\theta + \cos^2\theta) / \sin\theta$$
$$= 1 / \sin\theta$$
$$= \csc\theta, \text{ the equation of the envelope.}$$

The author acknowledges the kind assistance of Mr. Edgar Woolard in the discussion of these curves.

This discussion is an effort to combine in a manner which will be accessible to those interested, the chief factors involved in the effect of winds upon aircraft. In spite of the apparent simplicity of the question, there are many aviators and others who have not taken the trouble to think it through. It is hoped therefore that this discussion may serve a useful purpose. The author thanks the aeronautical department of the Goodyear Tire & Rubber Co. for permission to use charts and material on the navigation of airships set forth in one of that company's publications.[9]

Other graphical devices.—Another type of graphical illustration of the relations between wind direction and strength and the flight of aircraft has been made by Rev. Miguel Selga, of the Manila Observatory.[10] His method is to draw two circles of equal radii, but with the distance between the centers proportional to the ratio between wind speed and craft speed, e. g., if the craft speed is greater than wind sped, the centers of the two circles are less than their radius apart; if the speeds are equal, the center of one is on the circumference of the other; and, if the wind is greater than craft speed, the centers are a greater distance apart than the radius. With three such systems of circles, one is enabled to show vectorially the possible progress of the craft in any direction with a wind of constant direction, or, conversely, to show the progress along a given path with winds of various directions. These vectors are obtained by projecting horizontally the point on the wind circle corresponding to the direction from which the wind is coming, until it intersects the craft circle. A vector from the center of the wind circle drawn to the projected point on the craft circle represents the resultant motion. This method does not seem as satisfactory as that presented above, although it is of interest.

A mechanical device for correcting the route while in flight when the wind speed is unknown has been described by Lieut. Le Prieur.[11] Such devices would be useful in correcting data previously given to aircraft, and in following the changes of barometric pressure at upper levels

THE METEOROLOGIST AND COMMERCIAL AERONAUTICS.

The evolution of the meteorologist.—Just before digressing to take up the discussion of the effect of winds upon flight the question as to the aviator's ability to find the most satisfactory flying levels was raised. The pilot may feel that he can diagnose the air conditions sufficiently well to select his own flying levels; but at best this is only a method of trial and error, a method of approximation which not only is expensive in time and fuel but which, in the end, may be unsuccessful. It is no exaggeration to say that the meteorologist, properly equipped, can tell the aviator with more consistent accuracy where to fly than the pilot himself can determine. Most pilots are willing to admit this to-day, although it must be confessed that in the early days of the war many fliers were of the opinion that meteorologists were presuming a little to offer advice. Experience has shown both the value of such advices, and, indeed, the necessity for them. It is no longer a question of the presumptuous meteorologist and the pompous pilot, but of the pilot eager for more information and of the meteorologist exerting himself to the utmost to give it. In fact, so important has become the field of aeronautical meteorology that there exists to-day, and will exist to a much greater extent within a few years, a very interesting and extremely practical field for the new vocation of aeronautical meteorologist.

No more convincing proof of this point is to be found than that which comes from experience; and the experience of G. Holt Thomas on the London-Paris route, substantiates the argument. Regarding the maintenance of a meteorological department in his company, Mr. Thomas says:

> Years ago I was an ardent believer in the value of this science to the airman when he has to fly regularly; and the more I realize its potentialities, the more I know about it, the more I am convinced of the all-important part it must play in the development of commercial aeronautics.
>
> To this end, in our purely aerial transport enterprise we have, as I have already mentioned briefly, taken the step of forming our own meteorological department; and already, in the practical collaboration between this department and the pilots who are called on to fly from day to day, we have achieved results which are extremely interesting.
>
> * * * Having one's own meteorological department, ready always to answer questions is, as we have already proved, of the utmost value to an aerial transport enterprise operating machines daily along specified routes.

Again, H. B. Pratt, chief engineer of the airship department of the Vickers company, says:[12]

> Each aerodrome would contain a meteorological office working in association with Government meteorological stations, to issue weather reports for the guidance of airship navigators and to transmit navigating instructions by wireless telegraphy to them while in flight.

It appears therefore that the functions of a governmental meteorological agency must be twofold with respect to aeronautics. It must collect and disseminate meteorological data over the entire country, and it must conduct researches which will eventually have their reflection in increased accuracy of forecasting. The functions of the aeronautical meteorologist, by way of contrast, must be to interpret the collected data and to advise pilots in detail regarding the weather along their routes, and to care for numerous other requirements which will develop with his office.

AN EXAMPLE OF THE METEOROLOGIST'S WORK.

In approaching an intimate view of the work of the aeronautical meteorologist it is, of course, necessary to theorize; and, in theorizing, the author does not pretend to do more than suggest the activities which seem most likely to be essential, drawing upon the imagination for details which, with experience, might be found capable of great improvement. Such theorizing is necessary because there probably does not exist to-day on this side of the Atlantic a single enterprise which profits by the steady employment and the thoroughly organized activities of a meteorologist in connection with a flying route. If, then, practical objections may suggest themselves relative to the details of the following scheme, it should be remembered that the purpose is only to sketch broadly the activities of an office which does not yet exist.

Equipment.—The reader is, therefore, asked to imagine himself in the office of the meteorologist in the Blank Aerial Transport Corporation. The office is equipped, in addition to charts and diagrams which experience has demonstrated to be the most useful, with a relief model of the territory over which the aircraft of the Blank Corporation fly. The meteorologist is intimately familiar

[9] Goodyear Dirigible Balloon Operating Instructions, No. 202. Goodyear Tire & Rubber Co., Akron, Ohio.

[10] Selga, Miguel, S. J.: Velocidad del viento y de los dirigibles. *Revista de la Sociedad Astronómica de Espana y América*, September-October, 1920, pp. 83-85.

[11] Correcteur de route à dérivegraphe pour la navigation aérienne à l'estime. *L'Aerophile*, Nov. 1-15, 1920, pp. 326-332.

[12] Commercial Airships (London), 1920, p. 75.

with this territory and all the peculiarities which the irregularities of the terrain introduce into the meteorological phenomena in their vicinity; he is familiar with this not only through his knowledge of the physics of the atmosphere but also through first-hand experience in flying over the routes. Along the lines which join the principal cities and relay stations on the route are placed small vertical standards properly graduated so as to show altitude above sea-level. These standards are so arranged that at 500-meter levels (English units could be used, if necessary) small arrows could be placed so as to point in any direction. At each level there could be arrows of several different colors. In addition to these fixed standards, there are provided slots in the base, with small movable standards, each carrying a symbol representative of a given craft, and these standards can be moved at will to indicate the position of any machine at any time. There is wireless telephone apparatus in the office and all of the company's craft are equipped with similar apparatus, so that, at all times, the office can be in communication with its fliers. The meteorologist's office becomes, in a sense, a sort of dispatcher's office, and it not only keeps the pilots informed of weather conditions, but keeps close track of the position and progress of each craft.

Work.—With these brief and rather elemental notions of the meteorologist's equipment, let us endeavor to get some idea of his work. Through arrangement with the Weather Bureau, the meteorologist's office is in receipt of code messages giving the upper-air data as they are collected. As he begins his work in the morning the surface wind arrows on his relief model are set to correspond with the regular morning observations of the Weather Bureau; he has before him a copy of the morning weather map, drawn either in his office from the code message or furnished by the local Weather Bureau office. The upper-air wind arrows are set to show the conditions aloft corresponding to the last upper-air observations made at aerological stations during the night. And these are constantly being corrected upon the receipt of new observations. The flying weather forecast forms the basis of his bulletins, and these future conditions are set upon the relief model in arrows of another color, so as to distinguish them from the arrows representing observed conditions. Still other arrows may be set to represent conditions interpolated between the observed and the forecast, so that estimated conditions at any time can be seen readily. Upon the basis of this constant stream of observed and forecast data the meteorologist is enabled to issue extremely detailed reports or bulletins to his fliers at frequent intervals regarding winds, cloudiness, and visibility.

If conditions are normal, each pilot will communicate with the office every hour, giving his position and any information as to visibility, cloudiness, or unusual phenomena he may be encountering. This information keeps the meteorologist in immediate contact with the conditions and gives him a perspective which no other individual can have. There will be craft flying in each direction along all routes at all times and the office of the meteorologist thus will become an important clearing house for the latest information concerning the phenomena along the route.

Important phenomena.—There are many circumstances in which very definite and important phenomena are occurring; as, for example, the progress of the wind-shift line in a strong cyclone. The rate of progress of this line, the depth of the wind shift, and the occurrence of thunderstorms along it, are all conditions concerning which the pilot wants to know. Especially is this true of pilots of lighter-than-air craft. This system of hourly reporting, together with special reports when unusual conditions justify them, will more than pay for itself in the resultant efficiency. Once the craft is well under way, the meteorologist can tell the terminal station with considerable accuracy, barring mechanical accidents, when the craft will arrive there. This will be important for those concerned with the transportation of baggage to and from the airport; and it will mean untold convenience to the public which is to use the route.

WEATHER CONDITIONS ON AIR ROUTES.

Upper-air conditions on flying routes.—In figure 5, to show the nature of the use of upper-air information in this connection, the weather conditions have been drawn for several flying routes, giving especial regard to winds and their strength. Across the bottom of the figure is a map of several routes and above are sections along these routes showing direction and force of the wind. The New York-Omaha route has been given especial attention and the wind conditions drawn for 8 a. m., noon, and 3 p. m., 75th meridian time. The 8 a. m. and 3 p. m. data were observed and the noon section interpolated between the two. For the shorter routes, these conditions were shown for 8 a. m. only, since the time of a single flight would be so short as to fall under those representative conditions. In the wind speed and direction sections of the diagram the arrows show speed by barbs, each barb corresponding to 5 miles per hour, and the direction both by the orientation of the arrows and by small letters. The solid sections at the bottom of each section represent the general elevations of the country over which the route lies above sea level.

Above the wind direction and speed sections are shown curves indicating the speed of the parallel and perpendicular wind components in miles per hour for the three levels, 1, 2, and 3 kilometers above sea level. The ordinates of the curves show directly the magnitudes of the parallel component, while the perpendicular component is indicated by small numbers (miles per hour) at various points along the curve. It is easy to calculate from such data and other curves, such as those in the preceding figures, all the necessary information on flying conditions.

In Table 1 are given, for example, the length of time required for the flight between the various points, at various levels, both on the outward and return journeys, assuming an airplane whose speed in a calm would be 100 miles per hour.

TABLE 1.—*Time required for flight between various points at several levels, with a craft of still-air speed 100 miles per hour.*

Route between—	Distance.	Time. Outward. 1 kilometer.	Outward. 2 kilometers.	Outward. 3 kilometers.	Return. 1 kilometer.	Return. 2 kilometers.	Return. 3 kilometers.
	Miles.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
New York to Washington	200	2 48	3 00	3 00	1 36	1 34	1 34
New York to Cleveland	410	4 36	5 30	5 27	3 36	3 12	3 14
Cleveland to Chicago	320	3 54	4 18	4 42	2 45	2 36	2 24
Chicago to Omaha	440	4 42	6 00	6 40	4 18	3 48	3 20
Chicago to Twin Cities	350	3 42	3 48	4 42	3 18	3 24	2 54
Chicago to St. Louis	280	3 20	3 48	3 42	2 24	2 18	2 20
Chicago to Indianapolis	180	1 46	1 48	1 30	1 50	1 54	2 24

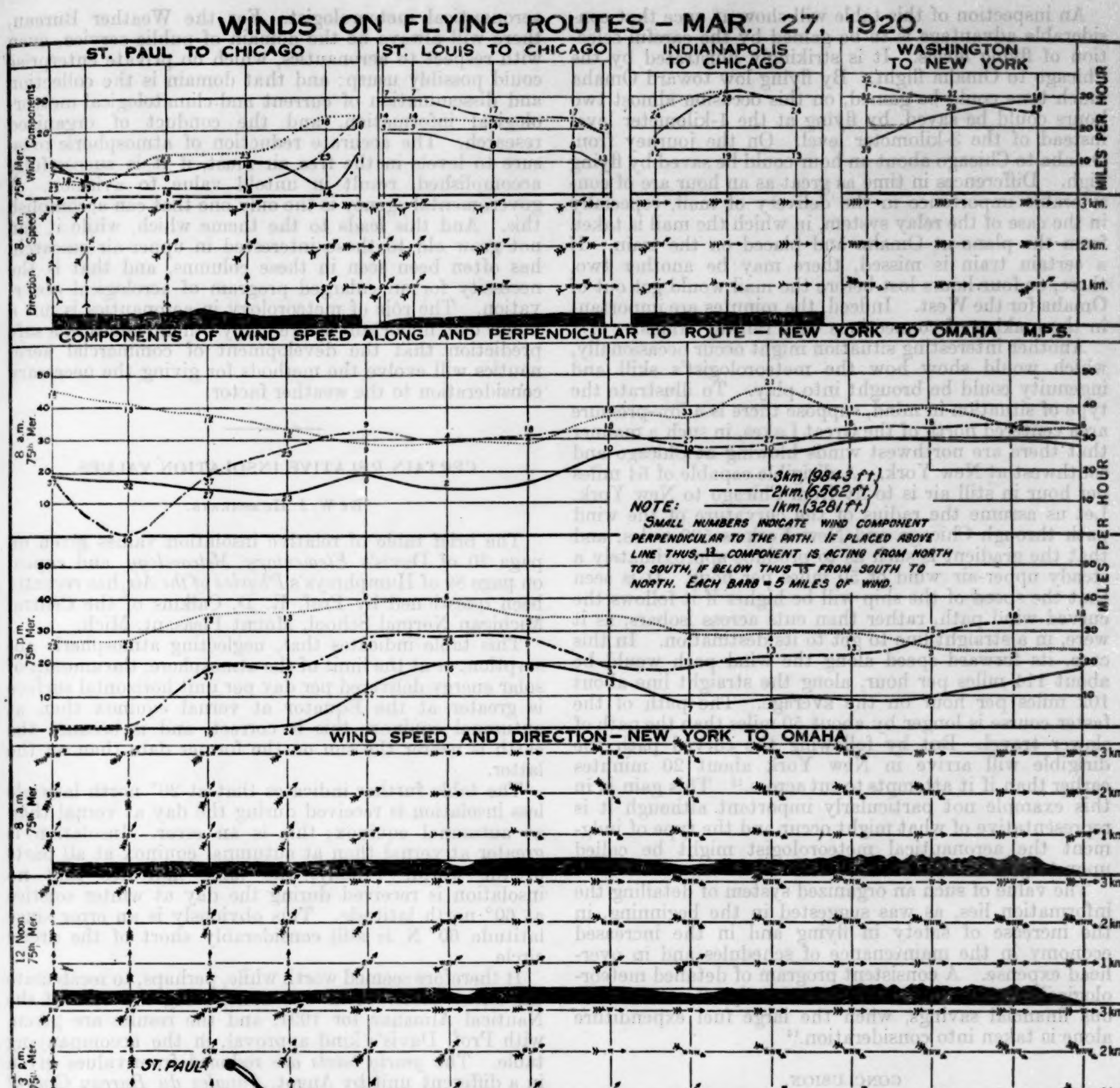

WINDS ON FLYING ROUTES - MAR. 27, 1920.
ST. PAUL TO CHICAGO
ST. LOUIS TO CHICAGO
INDIANAPOLIS TO CHICAGO
WASHINGTON TO NEW YORK
MILES PER HOUR
8 a.m. 75th Mer. Direction & Speed
75th Mer. Wind Components
3 km.
2 km.
1 km.
COMPONENTS OF WIND SPEED ALONG AND PERPENDICULAR TO ROUTE — NEW YORK TO OMAHA M.P.S.
8 a.m. 75th Mer.
3 p.m. 75th Mer.
3km. (9843 ft.)
2km. (6562 ft.)
1km. (3281 ft.)
NOTE:
SMALL NUMBERS INDICATE WIND COMPONENT PERPENDICULAR TO THE PATH. IF PLACED ABOVE LINE THUS, 15 COMPONENT IS ACTING FROM NORTH TO SOUTH, IF BELOW THUS 15 FROM SOUTH TO NORTH. EACH BARB = 5 MILES OF WIND.
WIND SPEED AND DIRECTION — NEW YORK TO OMAHA
12 Noon 75th Mer.
ST. PAUL
OMAHA
CHICAGO
INDIANAPOLIS
ST. LOUIS
CLEVELAND
NEW YORK
WASHINGTON

FIG. 5.

An inspection of this table will show at once that considerable advantage is to be gained by the careful selection of flying levels. It is strikingly illustrated by the Chicago to Omaha flight. By flying low toward Omaha much time could be gained, on this occasion almost two hours could be saved, by flying at the 1-kilometer level instead of the 3-kilometer level. On the journey from Omaha to Chicago about an hour could be saved by flying high. Differences in time as great as an hour are of considerable importance in the delivery of mail, especially in the case of the relay system, in which the mail is taken from the plane at Omaha and placed on the train. If a certain train is missed, there may be another two, three, or four hours lost before the mail would get out of Omaha for the West. Indeed, the minutes are important in the making of connections with railway trains.

Another interesting situation might occur occasionally, which would show how the meteorologist's skill and ingenuity could be brought into play. To illustrate the type of situation in mind, suppose there is a low-pressure area centered north of the Great Lakes, in such a manner that there are northwest winds blowing at Chicago and southwest at New York. A dirigible capable of 64 miles per hour in still air is to fly from Chicago to New York. Let us assume the radius of the curvature of the wind path through Chicago and New York is 500 miles, and that the gradient is such as to produce approximately a steady upper-air wind of 50 miles per hour. It is seen that the speed of the ship will be higher if it follows the curved wind path, rather than cuts across isobars, as it were, in a straight line to get to its destination. In this case, its forward speed along the wind path would be about 114 miles per hour, along the straight line about 102 miles per hour on the average. The path of the faster course is longer by about 50 miles than the path of slower travel. But by following the curved path the dirigible will arrive in New York about 20 minutes earlier than if it attempts to cut across.[13] This gain is in this example not particularly important although it is representative of what might occur and the type of judgment the aeronautical meteorologist might be called upon to possess.

The value of such an organized system of detailing the information lies, as was suggested in the beginning, in the increase of safety in flying and in the increased economy in the maintenance of schedules and in overhead expense. A consistent program of detailed meteorological information would undoubtedly effect tremendous financial savings, when the large fuel expenditure alone is taken into consideration.[14]

CONCLUSION.

It will suffice, in conclusion, to review briefly the essential points of the discussion. An effort was made to show that a consideration of the weather factor in aeronautics must lead to beneficial results in commercial aviation; and that the requirements of commercial aviation must eventually bring into being the vocation of aeronautical meteorologist. For the Weather Bureau, there will always be the domain of public service, even with respect to aeronautics, which no private enterprise could possibly usurp; and that domain is the collection and dissemination of current and climatological meteorological information, and the conduct of organized research. The accurate reduction of atmospheric pressure to levels in the free air must, if it is successfully accomplished, result in untold value to aviation. A governmental agency is the only one that can accomplish this. And this leads to the theme which, while it can not grow old to those interested in upper-air research, has often been seen in these columns, and that is the necessity for an enlarged program of aerological observation. The rôle of meteorology in aeronautics is not a minor one, important as are many others; and it is a safe prediction that the development of commercial aeronautics will evolve the methods for giving the necessary consideration to the weather factor.

[13] "Undoubtedly captains of the big aerial liners of the future will become wily and cunning masters of the art of selecting the right way and the right height and often, by making wide *détours*, will, by their air knowledge alone, save many hours on long sea and land passages."—Big. Gen. Maitland, in the log of the R. 34. *Commercial Airships*, Pratt. Appendix, p. 231.

[14] Report of Air Mail Service, October, 1920, *Aviation*, Jan. 10, 1921, p. 51. Cf. also DeHaviland on Civil Aviation, *Aerial Age Weekly*, Jan. 17, 1921, p. 486.

CERTAIN RELATIVE INSOLATION VALUES.

By W. J. HUMPHREYS.

The brief table of relative insolation values given on page 20 of Davis's *Elementary Meteorology*, and copied on page 80 of Humphreys's *Physics of the Air*, has recently been questioned by Prof. R. D. Calkins of the Central Michigan Normal School, Mount Pleasant, Mich.

This table indicates that, neglecting atmospheric absorption, or at the limit of the atmosphere, the amount of solar energy delivered per day per unit horizontal surface is greater at the Equator at vernal equinox than at autumnal equinox; this is correct, and is because the earth is nearer the sun on the former date than on the latter.

The table further indicates that at 20° north latitude less insolation is received during the day at vernal than at autumnal equinox; this is an error. Insolation is greater at vernal than at autumnal equinox at all parts of the world. Finally, the table indicates that no insolation is received during the day at winter solstice at 60° north latitude. This obviously is an error since latitude 60° N. is still considerably short of the arctic circle.

It therefore seemed worth while, perhaps, to recalculate the entire table. This was done, using the data of the Nautical Almanac for 1921, and the results are given, with Prof. Davis's kind approval, in the accompanying table. The *yearly totals* are reduced from values given in a different unit by Angot, *Annales du Bureau Central Météorologique*, for 1883.

Relative values of total diurnal insolation per unit horizontal surface at the limit of the atmosphere.

Latitude.	Equator.	20° N.	40° N.	60° N.	North Pole.	South Pole.
Vernal equinox	1.000	0.940	0.766	0.500	0.000	0.000
Summer solstice	0.882	1.044	1.107	1.093	1.201	0.000
Autumnal equinox	0.987	0.927	0.756	0.494	0.000	0.000
Winter solstice	0.941	0.676	0.357	0.056	0.000	1.283
Annual total	348	329	275	198	144	144

FIG. 1.—Fruit region instrument shelter in a pear orchard near Medford, Oreg.

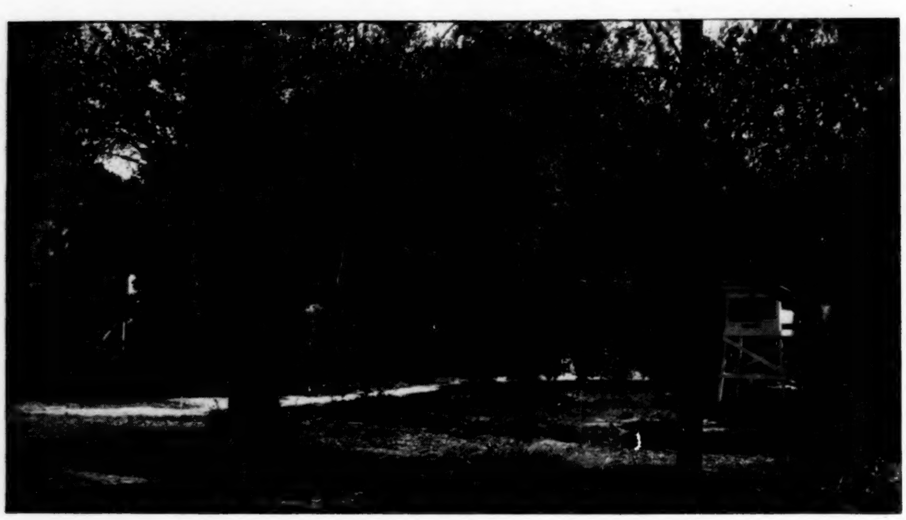


FIG. 2.—Cotton region (on left) and fruit region (right) instrument shelters used in making comparative readings of maximum and minimum temperature.

INFLUENCE OF EXPOSURE ON TEMPERATURE OBSERVATIONS.

By FLOYD D. YOUNG, Meteorologist.

[Weather Bureau Office, Portland, Oreg., Nov. 23, 1920.]

SYNOPSIS.

Although the daily temperature observations of the Weather Bureau are designed to indicate as nearly as possible the temperature of the free air surrounding the thermometers, it is not practicable to accomplish this exactly, on account of the influence of the character of the exposure of the thermometers on the readings. Both maximum and minimum temperatures are affected.

The fruit-region instrument shelter, designed to allow a freer circulation of air and lessen the disturbing effects of exposure, is described in this paper and compared with the cotton-region shelter in general use.

Data are given to show differences between current temperatures inside the fruit-region shelter and current readings of the dry bulb of the whirled psychrometer outside the shelter, at different locations and at different hours. After sundown radiation of heat from the roof and sides of the shelter reduces the temperature of the air in its interior below that of the outside air. Within certain limits, the stronger the radiation and the more quiescent the surrounding air, the greater will be the depression of the temperature inside the shelter below that outside.

Minimum temperatures recorded in different portions of the foliage of two lemon trees did not differ materially from those recorded inside a fruit-region instrument shelter, located between the two trees, all the thermometers being at the same height above the ground.

It is well known that a thermometer freely exposed to a clear sky at night will show a lower temperature than a similar thermometer located at the same height above the ground inside a standard Weather Bureau instrument shelter. The depression of the unsheltered thermometer is due principally to loss of heat by radiation to the sky, the thermometer, especially such parts as radiate heat readily, i. e., dull-surfaced metal, becoming colder than the air. Evaporation of moisture from the bulb of the exposed thermometer sometimes increases the difference between the sheltered and exposed thermometers, but as a general rule this factor is of little importance.

The difficulties in the way of obtaining accurate free-air temperatures are generally understood. It has recently been shown [1] that there may be considerable difference between extreme temperatures registered in two standard Weather Bureau shelters when one shelter is shaded from the open sky by a tree and the other stands in the open.

In making minimum temperature forecasts for a certain location it is evident that their verification will depend to a considerable extent on the exposure of the thermometer with which the temperatures are recorded. When minimum temperature forecasting was first begun by the Weather Bureau in the Rogue River Valley fruit district, orchardists were in a habit of checking up the official forecast for their district by comparing it with the temperature registered by their own thermometers, which were generally very poorly exposed, often without any shelter whatever. As a result, the forecasts were often criticised unjustly.

FRUIT-REGION SHELTER.

When special fruit-frost investigational work was begun in 1917 a new instrument shelter, patterned after the French type, was designed by Mr. B. C. Kadel, Chief of the Instrument Division, with a view to obtaining a freer circulation of the air and making it possible to obtain temperature readings that would more nearly approximate actual free-air temperatures. This shelter is shown in figure 1. The door, to face toward the north, is entirely open except for a covering of large mesh heavy wire screen. The bottom is open except for two narrow horizontal wooden strips to carry a thermograph and hygrograph. The bottom is also screened to prevent interference with the instruments. A small vertical wooden arm, attached to the front horizontal strip, carries the Townsend support and the maximum and minimum thermometers. Direct sunlight is excluded from the interior of the shelter on the back and sides by wide, overlapping boards, far enough apart to allow free movement of the air.

In order to determine how this shelter compares with the cotton region shelter of the Weather Bureau, a series of comparative maximum and minimum temperature readings were obtained at Pomona, Calif., during the winter of 1917–18. These are shown in Table 1.

The shelters were placed about 50 feet apart on level ground, in as nearly identical a position with regard to surrounding trees as possible. Both shelters were completely surrounded by orange and olive trees and were shaded from the sun during most of the day (see fig. 2).

Maximum temperatures registered in the fruit-region shelter were generally lower than those registered in the cotton-region shelter, especially on warm days. This would appear to be a result of better ventilation in the fruit-region shelter. There was very little difference between the daily minimum temperatures registered in the two shelters, especially on clear nights.

During the spring frost seasons of 1919 and 1920 a cotton region and a fruit region shelter were placed side by side in an open, unshaded space over grass-covered ground in the city of Medford, Oreg. Minimum temperatures registered in these shelters on clear nights are shown in Table 2. Differences never amounted to more than 0.9° F.

From an examination of Tables 1 and 2 it appears that for registering minimum temperatures the new type of shelter is only a slight improvement over the regular cotton-belt type in general use at cooperative stations.

COMPARISONS OF TEMPERATURES INSIDE AND OUTSIDE INSTRUMENT SHELTER.

During the progress of the fruit-frost investigational work at Pomona, Calif., and Medford, Oreg., a great many simultaneous readings of the minimum thermometer inside the shelter and the whirled sling psychrometer outside the shelter were made, mostly during the night. The fruit-region shelter was used in every case.

The Medford observations are shown in Table 3 and those taken at Pomona in Table 4. The earlier afternoon observations at Medford were made before the sun had set. At Pomona observations were never begun until after sunset.

As a general rule, the shelter temperature was somewhat higher, or nearly the same as the outside air temperature before sunset, and considerably lower than the outside temperature after 8 or 9 p. m. Differences between the shelter and outside temperatures were usually near the maximum at the time the minimum temperature was registered inside the shelter. Differences were greatest when the sky was clear, although high cirro-stratus clouds failed to affect the readings either inside or outside the shelter. These statements

[1] Flora, S. D.: Shading Instrument Shelters. MONTHLY WEATHER REVIEW, May, 1920, 48: 271–272.

would not be true if a stationary thermometer exposed in the open was substituted for the whirled dry bulb, for, as explained in the first paragraph of the article, the thermometer so exposed will usually be colder than the air at night.

With a rising temperature the natural lag of the alcohol minimum thermometer behind the dry bulb mercurial thermometer of the psychrometer would tend to cause the shelter temperature to appear lower than it actually was, but with a falling temperature, as was the case when most of the readings in Tables 3 and 4 were taken, the lag of the minimum thermometer would serve to lessen the difference between the temperature inside and outside the shelter.

Radiation of heat from the roof and sides of the shelter reduces the temperature of the air in its interior considerably below the temperature of the outside air, even when the bottom is practically open. Within certain limits, the stronger the radiation and the more quiescent the surrounding air, the greater the depression of the temperature inside the shelter below that outside. A current of air sufficient to cause a steady movement of air through the shelter may cause the minimum temperature to read one or two degrees higher than it would if the air were still. This being the case, it is rather surprising that minimum temperature forecasts are accurate within one degree as often as they are.

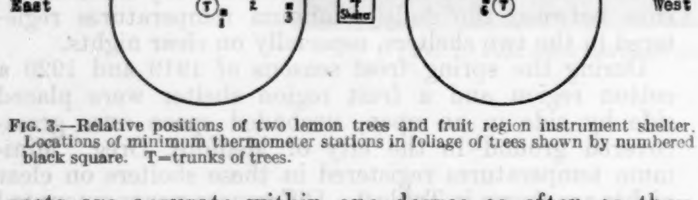


FIG. 3.—Relative positions of two lemon trees and fruit region instrument shelter. Locations of minimum thermometer stations in foliage of trees shown by numbered black square. T=trunks of trees.

To produce a flow of air through the shelter sufficient to bring the inside and outside temperatures into agreement, a sustained wind velocity of several miles per hour is required. Sudden temporary rises in temperature during the night of 3° F. or less, caused by a slight wind, are often not recorded either by the thermograph or the minimum thermometer in the shelter; both these instruments may show a stationary temperature at such a time. The observations between 10:08 p. m. and 11:39 p. m. on December 23, shown in Table 4, will serve to illustrate this.

TREE AND INSTRUMENT SHELTER TEMPERATURES COMPARED.

During the winter of 1917-18 minimum temperature readings were obtained in various portions of two heavily foliaged lemon trees and in a fruit region instrument shelter set between these trees, in order to determine how accurately the minimum temperature in the shelter represented the minimum inside the foliage. This experiment was initiated by Mr. William. G. Reed. Figure 3 shows the relative positions of the instruments in the trees and the instrument shelter. Minimum temperature observations from each station are given in Table 5.

To carry the minimum thermometers in the trees. Townsend supports were attached to small vertical boards fastened to the top of iron rods which were driven into the soft ground under the trees. Small horizontal boards partially sheltered the thermometers above, although the heavy foliage effectively screened them from the sky. The instrument shelter, set exactly between the two trees, was cut off from about a third of the sky, but as the trees were only about 12 feet high the roof was sheltered but little.

The extreme difference in average minimum temperature was 1° between stations 2 and 6. Contrary to expectation, the lowest average minimum was not found in the shelter, but at station 2. The temperature inside the shelter was undoubtedly depressed below the temperature of the outside air through radiation, but the dark leaves of the trees probably radiated sufficient heat to cool the air in the interior of the foliage to about the same extent.

The distribution of the average minimum temperatures at the different stations is probably due to the effect of the early morning sun. The eastern half of the tree receives the benefit of the sunlight first, and it is probable the small amount of radiant heat received while the sun is near the horizon is sufficient to prevent a further fall in temperature there, while the temperature in the portion of the tree facing toward the west may continue to fall for some little time afterwards.

CONCLUSION.

In view of the results described above, thermometers which are exposed in the open evidently will give better indications of actual air temperature if they are fastened to the trunk of a fruit tree within the foliage.

For verifying minimum temperature forecasts for a number of stations in the same section it is necessary to have as nearly uniform exposure for the minimum thermometers as possible at all stations.

For registering maximum temperatures the fruit-region instrument shelter probably is superior to the cotton-belt type, owing to better ventilation, but for registering minimum temperatures the new shelter does not appear to be much of an improvement.

Temperatures inside the fruit-region shelter are the same as, or higher than, the outside air temperature before sunset and lower than outside temperatures during the latter part of the night. At the time of the occurrence of the minimum temperature the depression of the shelter temperature is generally near the maximum for the night. The influence of exposure on minimum temperatures at least partially accounts for the lack of constancy in the difference between minimum temperatures at near-by stations on level ground.

TABLE 1.—*Daily maximum and minimum temperatures in cotton region and fruit region instrument shelters at Pomona, Calif.*

Date.	Maximum.		Departure.	Minimum.		Departure.
	Cotton region.	Fruit region.		Cotton region.	Fruit region.	
1918.	° F.	° F.	° F.	° F.	° F.	° F.
Jan. 3	72.3	70.3	−2.0	38.0	38.0	0.0
6	76.2	74.2	−2.0	[1] 31.0	[1] 31.0	0.0
7	70.2	69.0	−1.2	44.8	44.1	−0.7
8	62.9	62.8	−0.1	47.1	48.0	−0.9
9	61.9	60.9	−1.0	41.0	41.1	−0.1
10	65.3	65.3	0.0	[1] 30.0	[1] 30.0	0.0
12	63.7	63.3	−0.4	[1] 28.1	[1] 28.1	0.0
13	60.7	61.0	−0.3	37.8	37.9	−0.1
14	62.1	63.0	−0.9	33.0	33.0	0.0
15	59.8	59.7	−0.1	37.8	37.9	−0.1
Feb. 7	68.7	68.6	−0.1	48.2	48.1	−0.1
8	65.9	65.0	−0.9	[1] 33.0	[1] 33.0	0.0
9	78.4	77.2	−1.2	[1] 29.9	[1] 29.4	−0.5
18	58.3	58.1	−0.2	39.5	39.6	−0.1
20	56.7	57.2	−0.5	42.8	42.0	−0.8
21	64.1	65.0	−0.9	46.0	46.0	0.0
22	62.7	63.6	−0.9	50.0	50.0	0.0
23	68.0	67.9	−0.1	45.4	45.4	0.0

[1] Clear nights.

TABLE 2.—*Minimum temperatures on clear nights in cotton region and fruit region instrument shelters at Medford, Oreg.*

Date.	Cotton region.	Fruit region.	Departure.
1919.	°F.	°F.	°F.
April 7	28.4	29.0	+0.6
8	27.4	28.0	+0.6
11	28.0	28.9	+0.9
12	31.7	32.1	+0.4
14	26.6	27.0	+0.4
20	30.8	31.1	+0.3
26	31.9	32.1	+0.2
May 4	32.9	33.1	+0.2
5	32.0	32.7	+0.7
10	32.5	33.2	+0.7
13	33.0	33.6	+0.6
1920.			
April 11	31.8	31.8	0.0
14	34.9	34.9	0.0
16	35.0	35.0	0.0
17	33.6	33.7	+0.1
18	27.0	26.9	−0.1
20	32.0	32.0	0.0
22	28.4	28.1	−0.3
23	26.0	26.1	+0.1
24	29.5	30.0	+0.5
25	31.6	32.0	+0.4
29	34.0	34.0	0.0
May 2	32.5	32.8	+0.3
3	31.0	31.4	+0.4
4	31.1	31.4	+0.3

TABLE 3.—*Simultaneous current-temperature observations inside and outside fruit region instrument shelter at Medford, Oreg.*

Date and time.	Shelter temperature.	Air temperature.	Departure.	Clouds. Amount.	Clouds. Kind.	Dew-point.
1919.	°F.	°F.	°F.	0-10.		
Apr. 6-7:						
3:43 p. m.	56.0	56.0	0.0	6	Cu	32
4:48 p. m.	52.2	52.1	−0.1	6	Cu	32
6:46 p. m.	47.7	48.5	+0.8	6	Cu	35
7:20 p. m.	46.4	46.7	+0.3	7	Cu	32
8:25 p. m.	42.8	44.1	+1.3	4	Cu	33
8:58 p. m.	42.1	43.0	+0.9	3	Cu	33
9:28 p. m.	41.0	42.1	+1.1	1	St. Cu	33
9:59 p. m.	40.0	40.0	0.0	Few.	Cu	33
12:42 a. m.	33.9	35.3	+1.4	0	0	31
5:55 a. m.	32.9	33.3	+0.4	5	St.	31
Apr. 7-8:						
4:51 p. m.	57.2	57.3	+0.1	8	Ci. St	31
5:33 p. m.	54.1	54.2	+0.1	2	Cu	30
7:25 p. m.	46.6	46.6	0.0	0	0	30
12:05 a. m.	34.9	35.8	+0.9	0	0	29
12:31 a. m.	34.0	35.0	+1.0	0	0	29
12:59 a. m.	33.2	34.1	+0.9	0	0	29
1:30 a. m.	32.5	33.8	+1.3	0	0	29
2:02 a. m.	32.1	33.0	+0.9	0	0	31
5:57 a. m.	28.2	29.7	+1.5	3	St.	27
Apr. 10-11:						
4:45 p. m.	57.5	57.9	+0.4	6	Cu	32
5:50 p. m.	55.0	54.7	−0.3	5	Cu	28
6:40 p. m.	52.2	52.0	−0.2	4	Cu	27
7:38 p. m.	47.4	47.5	+0.1	3	Cu	27
8:01 p. m.	45.9	46.0	+0.1	3	Cu	27
11:30 p. m.	36.4	38.0	+1.6	3	Ci. St	28
12:29 a. m.	34.8	35.4	+0.6	2	Ci. St	28
1:04 a. m.	33.9	34.7	+0.8	Few.	Ci. St	28
6:29 a. m.	29.9	32.0	+2.1	0	0	30
Apr. 11-12:						
4:44 p. m.	63.0	62.2	−0.8	10	Ci. St	31
5:47 p. m.	61.1	61.0	−0.1	3	Ci. St	27
7:06 p. m.	53.0	52.0	−1.0	3	Ci. St	35
7:38 p. m.	49.1	49.8	+0.7	3	Ci. St	35
8:08 p. m.	48.0	48.9	+0.9	4	Ci. St	34
8:50 p. m.	46.0	47.2	+1.2	5	Ci. St	34
2:07 a. m.	37.0	38.0	+1.0	6	Ci. St	32
2:58 a. m.	35.0	35.8	+0.8	1	Ci. St	31
3:30 a. m.	34.0	35.8	+1.8	0	0	31
Apr. 19-20:						
3:43 p. m.	53.8	54.2	+0.4	9	St. Cu	40
4:47 p. m.	54.1	54.0	−0.1	9	St. Cu	39
5:51 p. m.	52.6	53.0	+0.4	6	St. Cu	39
7:23 p. m.	49.9	50.2	+0.3	3	St. Cu	40
8:34 p. m.	45.0	45.4	+0.4	1	Cu	41
9:00 p. m.	44.1	45.0	+0.9	Few.	St. Cu	39
9:28 p. m.	42.8	44.1	+1.3	Few.	St. Cu	39
9:59 p. m.	41.3	42.2	+0.9	Few.	St. Cu	38
10:27 p. m.	41.6	43.0	+1.4	0	0	38
11:03 p. m.	40.2	41.2	+1.0	0	0	38
3:21 a. m.	33.7	34.3	+0.6	0	0	32
5:44 a. m.	31.1	32.5	+1.4	3	St. Cu	32
May 4-5:						
3:38 p. m.	78.0	74.8	−3.2	0	0	37
4:38 p. m.	75.9	75.8	−0.1	0	0	37
5:29 p. m.	73.8	73.0	−0.8	0	0	31
6:32 p. m.	67.6	67.0	−0.6	0	0	31
8:31 p. m.	56.0	55.4	−0.6	0	0	31
8:57 p. m.	53.0	53.0	0.0	0	0	32
2:43 a. m.	36.8	38.3	+1.5	0	0	28
6:45 a. m.	41.0	42.2	+1.2	0	0	32

Shelter temperature is current reading of minimum thermometer inside instrument shelter. Air temperature is reading of dry-bulb thermometer of sling psychrometer after whirling.

TABLE 4.—*Simultaneous current-temperature observations inside and outside fruit region instrument shelter at Pomona, Calif.*

Date and time.	Shelter temperature.	Air temperature.	Departure.	Clouds. Amount.	Clouds. Kind.	Dew point.
1918.	°F.	°F.	°F.	0-10.		
Dec. 23-24:						
7:10 p. m.	35.0	36.0	+1.0	0	0	34
7:40 p. m.	35.0	35.6	+0.6	0	0	34
8:12 p. m.	33.4	34.3	+0.9	0	0	34
8:41 p. m.	32.2	32.7	+0.5	0	0	31
9:07 p. m.	31.4	32.2	+0.8	0	0	31
9:39 p. m.	31.9	32.5	+0.6	0	0	31
10:08 p. m.	30.2	30.6	+0.4	0	0	29
10:38 p. m.	31.9	35.0	+3.1	0	0	32
11:07 p. m.	30.9	30.9	0.0	0	0	29
11:39 p. m.	30.1	30.8	+0.7	0	0	29
12:07 a. m.	30.0	30.2	+0.2	0	0	30
12:42 a. m.	29.7	30.0	+0.3	1	A. St.	30
1:10 a. m.	29.1	30.1	+1.0	1	A. St.	30
1:37 a. m.	28.8	29.2	+0.4	0	0	29
2:10 a. m.	29.3	31.9	+2.6	0	0	29
2:37 a. m.	29.1	30.0	+0.9	0	0	27
3:06 a. m.	28.7	29.8	+1.1	0	0	27
3:35 a. m.	28.6	29.7	+1.1	0	0	27
4:06 a. m.	27.5	28.5	+1.0	0	0	27
4:35 a. m.	26.7	27.9	+1.2	0	0	26
5:05 a. m.	26.8	27.2	+0.4	0	0	26
5:37 a. m.	26.0	26.8	+0.8	0	0	25
6:07 a. m.	25.9	26.7	+0.8	0	0	25
6:38 a. m.	25.8	27.1	+1.3	0	0	24
7:06 a. m.	25.4	26.6	+1.2	0	0	25
1919.						
Nov. 27-28:						
6:43 p. m.	37.5	37.6	+0.1	5	St.	24
7:36 p. m.	35.0	35.4	+0.4	0	0	25
8:27 p. m.	35.4	37.1	+1.7	0	0	23
8:57 p. m.	33.4	33.7	+0.3	0	0	25
9:27 p. m.	31.8	31.7	−0.1	0	0	26
10:26 p. m.	29.5	31.0	+1.5	0	0	26
11:27 p. m.	29.9	31.0	+1.1	0	0	23
4:43 a. m.	26.2	27.6	+1.4	0	0	25
Dec. 13-14:						
6:30 p. m.	40.1	42.1	+2.0	0	0	30
6:56 p. m.	39.7	40.7	+1.0	1	Ci.	20
7:27 p. m.	39.0	41.0	+2.0	0	0	24
7:57 p. m.	37.9	38.8	+0.9	0	0	27
8:27 p. m.	35.4	36.2	+0.8	0	0	28
8:58 p. m.	34.2	35.6	+1.4	0	0	29
1:27 a. m.	32.8	34.1	+1.3	1	Ci.	20
1:54 a. m.	32.1	33.6	+1.5	2	Ci. St.	21
4:26 a. m.	32.3	34.1	+1.8	9	Ci. St.	20

Shelter temperature is current reading of minimum thermometer inside instrument shelter. Air temperature is reading of dry-bulb thermometer of sling psychrometer after whirling.

TABLE 5.—*Minimum temperatures in various locations in lemon trees and in fruit-region shelter.*

Date.	Station numbers.[1] 1	2	3	4	5	6
1917.	°F.	°F.	°F.	°F (shelter.)	°F.	°F.
Dec. 18	37.0	36.9	37.0	37.0	37.0	37.0
19	38.5	38.0	38.1	38.1	38.5	38.9
20	34.5	34.0	34.2	34.2	34.6	35.0
21	36.9	36.6	36.9	36.9	37.0	37.8
22	32.5	32.0	32.6	32.6	32.8	33.0
23	37.9	37.5	38.0	37.9	38.0	38.0
24	42.9	42.2	42.9	42.5	42.9	43.5
25	36.0	35.2	35.6	35.4	35.9	36.0
26	34.9	34.0	34.1	34.8	34.5	35.1
27	33.9	33.1	33.6	34.0	34.0	33.9
28	37.6	37.0	37.1	37.1	37.8	38.0
29	35.0	35.5	35.5	35.5	35.9	36.0
30	37.0	36.8	37.2	37.0	37.5	38.9
31	34.9	34.3	34.9	33.8	35.0	35.0
1918.						
Jan. 1	34.0	33.8	34.0	34.5	34.1	35.0
2	31.0	30.3	30.8	31.0	31.2	31.9
Average	35.9	35.4	35.8	35.8	36.0	36.4

[1] *See* fig. 3.

DIFFERENCES BETWEEN THE READINGS OF SHELTERED AND UNSHELTERED THERMOMETERS IN FIELD WORK.

By H. J. Cox.

[Presented before the American Meteorological Society at Chicago, Dec. 29, 1920.]

(Author's abstract.)

The subject of the exposure of thermometers in the field should always be given careful consideration, and

the character of the environment should be fully described, along with the published figures. The readings of unsheltered instruments are actually only the temperatures of the thermometers themselves, but they approximately represent the surface temperature of both the vegetation upon which they rest and of the fruit in the immediate vicinity, and not the temperature of the air. The heat lost by an unsheltered thermometer, especially on clear nights, is greater in a more or less degree than that indicated by a sheltered instrument close by.

During a research in the Wisconsin cranberry marshes minimum thermometers exposed in the open invariably read lower in clear weather than sheltered instruments; and over dense vegetation on clear nights differences ranging from 4 to 9 degrees (F.) were observed.

During a research in the orchards in the Carolina Mountain region minimum thermometers fastened to shelters 5 feet 6 inches above the ground usually read during cloudy weather about the same as thermometers within the shelters at the same height, but in clear weather the unsheltered instruments always read lower, but seldom more than 3 degrees (F); the differences not being as great as in the cranberry marshes because the instruments were farther away from the ground and in sections usually where the vegetation was not so dense. The differences were smaller when fresh to strong winds prevailed.

THE COMPARISON OF THE INDICATIONS OF SOME HOUSE THERMOMETERS IN WINTER. RESULTS OF OBSERVATIONS.[1]

By HENRY I. BALDWIN.

(Saranac Lake, N. Y., May 3, 1920.)

SYNOPSIS.

In the comparison of 197 outdoor household thermometers with a sling psychrometer at temperatures ranging from 0° to −30° F., it was found that there was a mean error of 3.2° F. as compared with the psychrometer, the amount of error increasing with decrease in temperature. Of the number tested 120 gave a reading too high, and 68 a reading too low, while 9 were correct at the observed temperature. The greatest error found was 30° F.

It is a common occurrence in a small mountain community that whenever the mercury drops considerably below zero on a still winter morning many conflicting reports are circulated regarding the temperature. There are various popular explanations for these discrepancies, including a vague idea that some parts of a town are colder than others, but there exists little definite knowledge on the subject. It was with a view of ascertaining more definitely the cause of these variations that the following observations were made. It was originally planned to make a complete thermometer census of the village of Saranac Lake, N. Y., under a wide range of temperature conditions, but this was found to be impracticable in the available time. The author fully realizes the limitations of the above observations, owing to the many factors not considered, but hopes that the results may be of some interest if not of much practical value.

Observations were made between 7:15 and 8 a. m., it having previously been determined that no appreciable rise in temperature occurred during that period. The weather conditions were chosen as nearly the same on the different days as possible, cloudless and still mornings being selected. The temperature reading with which the readings of the household thermometers were compared was obtained by taking the mean of three readings of a Green's No. 150 sling psychrometer whirled near the house thermometer. In the following results the readings of this psychrometer are referred to by concession as "standard," and it is assumed that no variation occurred in the instrument during the observations.

To insure this the psychrometer was kept as much as possible at a uniformly low temperature. As the exposure of the thermometers tested differed in nearly every case, and but a few were attached to trees, or objects separated from heated houses, little comparison can be made among them. However, the observations made close to, and applying to one thermometer only, are sufficient for our purposes of showing the errors of individual thermometers. It must, of course, be understood that the arbitrary corrections applied to the different thermometers in the tables hold true only for that particular temperature at which they were checked.

About twice as many thermometers read too high as too low, and it was noticed that it was generally the cheaper alcohol thermometers which read too low, while the majority of the mercurial thermometers read too high. The mean variation from the standard of the 197 thermometers tested was found to be 3.23° F., the error increasing from 2.21° at 0° F. to 4.18° at −28° F. Incidentally some of the series of observations illustrated very well the variations of temperature due to topographic conditions, and shows that these variations are independent of differences in thermometers. In figure 1 the readings of the sling thermometer are plotted beside

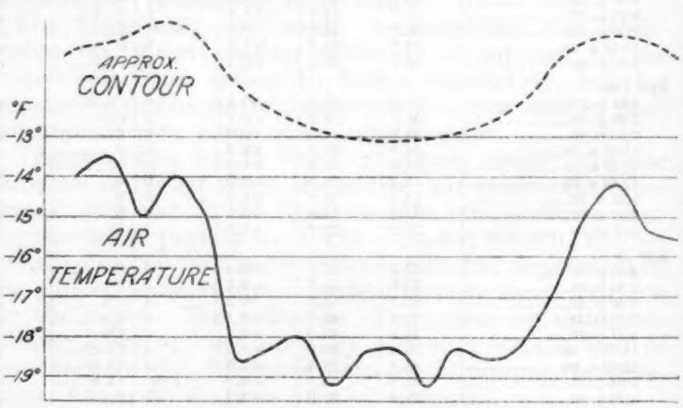


FIG. 1.—Valley profile and corresponding air temperatures near the ground at about sunrise on clear, quiet winter mornings. Saranac Lake, N. Y., winter of 1919–20.

an approximate profile of the ground covered in the observations, and demonstrate the effect of topography on the distribution of surface temperatures at about sunrise on clear, quiet, winter mornings.[1]

Errors in thermometers arise chiefly from three causes: First, from the contraction of the glass and change in the thermometer fluid with age; second, from the differential expansion of the scale and the glass (where the scale is not marked on the glass); and, third, from faulty exposure and ventilation.

The occurrence of minus errors in alcohol thermometers can be explained by the instability of alcohol as a thermometer fluid. It evaporates readily, and hence thermometers are filled at a low temperature, causing a high pressure to be developed when heated. Alcohol is hard to obtain in uniform quality, and has a tendency to form other compounds. However, the coefficient of expansion of alcohol is about 6 times that of mercury,

[1] The detailed tables and numerical summaries of the numerical departures are on file at the central office of the Weather Bureau, Washington, D. C.

which makes inappreciable any errors arising from change in the freezing point with the aging of the glass. This together with its low freezing point makes alcohol valuable for low-temperature thermometers, but great care must be exercised in their manufacture if they are to be at all accurate. Thus alcohol thermometers are liable to read too low because of age, especially if exposed to direct sunlight, which causes a change in the nature of the alcohol or the contained compounds.

The reason for the greater number of mercury thermometers reading too high is doubtless the contraction of the glass with age. While the scale is not marked on the glass in most cheap thermometers, the aging of the glass operates in the same manner in lifting the freezing mark, assuming that the thermometer is rigidly attached to the scale. If the scale slips, another irregular error will, of course, be introduced. It has been found that a thermometer graduated the day it is filled will read 1.5° higher a week later; if not graduated for one and a half years after filling, it will still read 0.5° too high in 6 years. Subjecting a thermometer to a low temperature, as −40° F., also appears slightly to raise the freezing point.

Other errors in thermometers result from faulty exposure and ventilation. A thermometer hung against the wall of a house, for instance, does not show the exact air temperature in cold weather, being influenced by conduction and radiation from the heated house. It is therefore better to hang a thermometer on a porch post, or support it at a distance from a window, than to fasten it directly to the wall.

During clear nights, especially during the winter in the middle and higher latitudes, it is observed that in calm weather the valleys are colder than the surrounding hills up to a certain altitude. The cause of this phenomenon is the nocturnal radiation from the surface of the earth into space. A deep snow cover intensifies the effect. The resulting cooling of the ground cools the adjacent layer of air, and since cold air is heavier than warm, the coldest layers lie nearest the ground in calm weather. Where the surface is not level, it follows that these cold layers of air flow down into the hollows, thus making them colder on still winter nights than the inclosing uplands.

CONCLUSIONS.

(1) The average outdoor household thermometer is about 3° (F.) in error at low temperatures.

(2) Most thermometers read too high. Alcohol thermometers read too low.

(3) The amount of error increases with extremes of temperature.

(4) The variations in the reports of low temperatures in a mountain community are due to—

(*a*) Faulty construction, calibration, and exposure of the thermometer, and its age.

(*b*) Topographical factors affecting the location of the thermometer.

Condensed table of mean deviations from the standard thermometer.

Number of observations.	Mean standard temperature.	Mean error.	Number of observations.	Mean standard temperature.	Mean error.
23	− 1.2	2.2	19	−22.5	3.7
44	−10.1	2.9	23	−27.0	3.8
64	−15.9	3.1	24	−28.1	4.2

TEMPERATURE AND RELATIVE HUMIDITY IN COLD STORAGE PLANTS FOR EGGS AND CANDY.

By OWEN T. LAY, Observer.

[U. S. Weather Bureau, Chicago, Ill. Jan. 8, 1921.]

SYNOPSIS

An account of the writer's experience in an investigation of aqueous vapor in its relation to certain cold storage problems. Following are some of the points discussed:

1. The temperature should be kept low for eggs and moderate for most kinds of candy.
2. The relative humidity should be comparatively high for eggs and low for candy.
3. The sling psychrometer was found to be the most practicable method of finding the relative humidity in different parts of the storage rooms.
4. The demand for such work has steadily increased in Chicago.
5. The probability that there is a latent field for such specialized work in other commercial centers.

Early in 1918 the writer was requested by the manager of one of the largest and most modern cold storage plants in Chicago to assist in an investigation of aqueous vapor in its relation to certain cold storage problems, especially in the storage of eggs.

In order to preserve eggs fresh successfully it is of course necessary for them to be so handled that the life germ (in those that are fertile) is kept dormant, this generally being accomplished by providing a uniform temperature slightly above their freezing point, which is near 28° but varies somewhat with the time of year when laid; and at the same time, keeping the air in the storage room pure, with just the right amount of well diffused water vapor. If the relative humidity is too low the interior moisture of the egg will escape, resulting in a loss in weight and a product that must be placed on the market at a loss as "shrunken;" while, on the other hand, if a high relative humidity obtains for any considerable period mold will form on the cases, fillers, and eggs and affect the flavor seriously.

Throughout the first season, closing in January, 1919, humidity inspections were made biweekly in eight rooms, containing approximately 20,000 cases each, it being found that in these heavily insulated rooms which were kept sealed almost constantly, the temperature could be held within 0.5° of the desired degree and the relative humidity held quite constant, although tending to increase gradually as the season advanced. To combat this increase varying quantities of unslaked lime were introduced and at times calcium chloride boxes were used in conjunction with electric fans. However, it was learned that the arbitrary standard of about 88 per cent for the relative humidity was too high, this percentage having been thought about right by many experienced cold storage men; hence, readjustment to a lower percentage was found advisable for the second season, which extended from May, 1919, to January, 1920.

During the second season 14 rooms in the same plant, containing about 250,000 cases, were inspected weekly. Through study of the data gathered during the preceding season, much more desirable results were secured; while, during the third season, closing with January, 1921, the work was expanded to include four storage houses, with about 600,000 cases of eggs and 10,000,000 pounds of candy. The candy included chocolate creams, chocolate nut bars, caramels, hard candies, etc., two ozone machines being used occasionally in keeping the air clean. Most kinds of candy keep best in a dry room, with moderate temperature.

Thanks to the zealous care of those in charge of the mechanical side of the cold storage houses, the practical

experience of the superintendents and some of the temperature control men, who now have a basis of carefully compiled data for their own building, reports indicate that the season now closing has been remarkably successful, compliments from customers being general at the time of removal of goods, with no complaints yet made, although some of the eggs have been held eight or more months and some of the candy for about one year.

It has been found that sling psychrometer readings are the most practical method of finding the relative humidity in different portions of the rooms, a special cold storage instrument graduated to tenths of degrees being very convenient, as well as exact, if carefully used. However, this instrument is intended only for readings of 40° or lower and can not be used in some candy storage rooms. Graphs are prepared for each room to show the progressive trend of temperature and humidity, temperature readings being taken every four to six hours. At the time the product goes out of storage the factors influencing its condition are plotted for comparison with the ideal sought.

The investigation has included brick, concrete, and wooden buildings, with different methods of refrigeration and various kinds of insulation. As a result of the facts learned, the firm for which this line of work was first undertaken is now reconstructing a large warehouse so that the factors of temperature, humidity ,and air circulation may be absolutely controlled mechanically, thus enabling them to handle such products as eggs and candy under exactly the conditions desired at all times.

Some of the reasons which influence practical business men to demand such a special service from an outsider are: (1) That the man so employed may combine his training with an ever broadening experience with different firms and in various kinds of plants so as to act as an adviser in new problems which arise from time to time; (2) that he will be in a position to give warning of any departures from a standard margin of safety and suggest means for their immediate correction; (3) that he may serve as an unbiased check upon regular employees who might be inclined to relax vigilance at times; (4) the fact of their having an outsider on the alert for any possible improvements in handling goods has a real value in securing business in competition with other firms which may be drifting along by rule of thumb.

In view of the increasing local interest in temperature and humidity control in the storage of foods and in many problems of manufacture, it would seem that there is a latent field for specialized work in each of the large commercial centers of the country.

THE DISTRIBUTION OF CLIMATOLOGICAL STATIONS.

By CLARENCE J. ROOT, Meteorologist.

[Weather Bureau, Springfield, Ill., 1920.]

In an article appearing in the February, 1920, number of the "*Bulletin of the American Meteorological Society*," Prof. J. Warren Smith is quoted as saying:

An expression of opinion should be obtained also in connection with temperature records. Do we have enough of these? Do we have too many at present, and should part of the money now expended in that connection be put into more rainfall records?

The statements that follow are written for the purpose of bringing out a discussion of the subject, and the opinions of men who have had experience in climatological work would be valuable and interesting.

In an area with varied topographical conditions, a large number of temperature and all-year precipitation stations are no doubt needed, but Illinois, with the exception of its two hilly areas, is an almost level prairie. The influence of Lake Michigan is felt in the extreme northeast portion of the State. Does Illinois need 64 full all-year weather stations, with 6 regular stations on its immediate borders but in other States?

Illinois is the second agricultural State in the Union, and the needs of agriculture should be given prime consideration. Except in the hill areas and near Lake Michigan, the temperature differences are principally those of latitude and the movements of cyclonic disturbances. The distribution of precipitation during the winter six months is quite uniform over rather large areas. During the summer months, and to a large extent in the spring and fall, the rainfall is of the local shower type. Great variations, both as to amount and time, occur over very limited areas, and here the question arises, Have we enough precipitation stations in Illinois during the crop-growing season?

There is another argument in favor of increasing the number of summer precipitation stations rather than to establish additional all-year stations. It requires considerable skill to properly handle the precipitation feature during the winter, and acceptable observers can not be found in every community. Then, too, the extra work of making snowfall measurements, and the inclement weather in which the duties must be performed, deter many from undertaking the obligation. On the other hand, almost any one would be glad to measure summer showers for the Government and the duties are so simple that any reliable person would be acceptable for this service. He would make entries only in column 7, Form 1009, Meteorological.

As an experiment, the writer prepared two maps of the State (Illinois), one showing the effect of enforcing the 25-mile limitation, and the other showing the effect of a 40-mile limitation for the all-year stations. A compass was set for a radius of 40 miles and circles were drawn about the regular station in and bordering on Illinois. Then places such as Rockford (an important city), and Urbana (the University of Illinois) were selected as permanent stations. Circles were then drawn about other stations in such manner as to give a good geographical distribution. The stations falling within the radii of these circles were considered unnecessary. An enforcement of the 25-mile limit would reduce the number of full stations (temperature and precipitation) from 64 to 41. The 40-mile limitation would reduce the number from 64 to 24.

It might be advisable to establish 175 crop-season rainfall stations in the State. With the 24 all-year stations, there would be about 200 summer precipitation stations, or about an average of two to a county. The money saved in thermometers, shelters, and supports should more than offset the expense of the additional rain gages.

A COMPARISON OF TWO TYPES OF EVAPORATION PANS.[1]

By G. A. LOVELAND, Meteorologist.

[Weather Bureau Office, Lincoln, Nebr., Jan. 26, 1921.]

SYNOPSIS.

The Briggs pan has a relatively large amount of water in a tank set in the ground with the top of the tank near the surface of the ground. The Weather Bureau tank has much less water and is placed all above the ground. The Weather Bureau tank evaporates from 30 per cent to nearly 50 per cent more water than the Briggs pan. The difference seems to depend more on the air temperature than on any other weather element. The tables give these differences in detail.

In the spring of 1917, a standard Weather Bureau evaporation pan was installed at the Agricultural experiment farm, Lincoln, Nebr. As this pan differed somewhat from the pan previously used to measure evaporation at the farm and from others in the State it seemed best to test the two types of pans by a series of observations with the two pans as nearly as possible similarly exposed to the weather.

The standard Weather Bureau pan is round, 4 feet in diameter and 10 inches deep. It was placed about 4 inches above the ground on wooden supports with air touching the sides and bottom. The water was kept about 4 inches below the top of the pan.

The other, or Briggs type of pan, is 7½ feet in diameter and 2 feet deep. It was set in the ordinary loess soil of the region, surrounded by grass. The top of the pan was flush with the ground. The water was kept as near as possible 4 inches below the top of the pan.

The tables give the monthly values of evaporation for the past four summers with some other related data, together with the differences in the monthly amounts and the percentage this difference is of the amount of evaporation in the Briggs pan.

The temperature and rainfall records were kept from standard instruments properly exposed near the pans. The anemometer, from which the wind velocity records were taken, was placed near the rim of the Weather Bureau pan, with the cups 5 inches above the top, which made them 19 inches above the Briggs pan. The relative humidity was taken from the records of the Lincoln station located about 3 miles distant.

It is realized that a 4-year record is too short to determine the laws controlling the differences in the readings, but some facts can be brought out that are interesting and valuable. The Weather Bureau pan consistently evaporated the most water with a large percentage of increase which varied considerably in different months. With three years' record in May and September and four years in the other months on the average for the season the Weather Bureau pan evaporated 43 per cent more than the Briggs pan—that is, the amount of evaporation measured in the Briggs pan multiplied by 1.43 would yield very approximately the amount that would be recorded in a Weather Bureau pan. On the other hand, the amount measured in a Weather Bureau pan multiplied by 0.70 would give the measurements of the Briggs pan.[2]

This short record seems to demonstrate the necessity of care in using the measurements from the two pans and the advisability of adopting as rapidly as possible the standard pan for all measurements of evaporation.

The reason for the larger evaporation of the Weather Bureau pan is due to the effect of the various and varying meteorological elements on the two types of pans. The smaller pan with the surface of the water somewhat higher and so more exposed to air movement and changes in temperature would result in a greater evaporation.

TABLE 1.—*Comparison of evaporation from Briggs and Weather Bureau pans.*

Month.	Year.	Evaporation.				Temperature.			Wind (miles per hour).	Humidity.	Precipitation.
		Briggs pan.	Weather Bureau pan.	Difference.	Difference.[1]	Mean maximum.	Mean minimum.	Mean.			
		Inches.	*Inches.*	*Inches.*	*P. ct.*	° *F.*	° *F.*	° *F.*		*P. ct.*	*Inches.*
May	1917	5.155	5.706	0.551	0.107	69	45	57	5.1	64	4.11
	1918	7.108	9.155	2.047	.288	80	54	67	6.9	60	3.04
	1919	......	6.049	......	......	70	49	59	3.2	68	1.55
	1920	3.281	5.508	2.227	.679	71	50	61	3.9	72	5.11
	Sums	15.544	26.418	4.825	......	......	......	......	......	......	......
	Average	5.181	6.603	1.608	.358	......	......	......	4.8	66	......
June	1917	6.915	9.273	2.358	0.341	80	58	69	4.2	63	6.39
	1918	7.452	10.561	3.109	.417	90	63	76	3.8	59	2.29
	1919	4.912	7.045	2.133	.434	81	62	71	2.8	75	6.78
	1920	6.264	8.277	2.013	.321	83	62	72	3.5	62	2.05
	Sums	25.543	35.156	9.613	......	......	......	......	......	......	......
	Average	6.386	8.789	2.403	.378	......	......	......	3.6	65	......
July	1917	7.455	10.523	3.068	0.412	91	64	77	3.2	59	0.77
	1918	6.861	10.138	3.277	.478	90	65	77	3.8	59	2.18
	1919	7.995	11.700	3.705	.463	94	68	81	3.0	59	0.20
	1920	6.063	8.641	2.578	.425	88	63	76	2.1	62	3.77
	Sums	28.374	41.002	12.628	......	......	......	......	......	......	......
	Average	7.094	10.250	3.157	.444	......	......	......	3.0	60	......
Aug	1917	5.351	7.528	2.177	0.407	85	58	71	2.6	70	3.52
	1918	7.567	11.548	3.981	.526	95	67	81	4.2	57	0.72
	1919	6.083	9.101	3.018	.496	86	62	74	2.8	66	3.50
	1920	4.683	6.189	1.506	.322	83	59	71	1.1	67	4.83
	Sums	23.684	34.366	10.682	......	......	......	......	......	......	......
	Average	5.921	8.592	2.670	.438	......	......	......	2.7	65	......
Sept	1917	......	5.408	......	......	79	54	66	3.2	72	2.22
	1918	4.761	7.467	2.706	0.568	73	47	60	4.4	59	1.71
	1919	4.791	7.150	2.359	.492	82	59	70	3.7	67	5.33
	1920	4.283	6.425	2.142	.500	82	55	68	2.7	68	1.18
	Sums	13.835	26.450	7.207	......	......	......	......	......	......	......
	Average	4.612	6.612	2.402	.520	......	......	......	3.5	66	......
Oct	1917	4.296	5.574	1.278	0.297	67	37	52	4.3	57	0.42
	1918	2.877	4.765	1.888	.656	68	47	57	4.9	70	4.96
	1919	2.105	2.616	0.511	.243	60	40	50	3.6	77	1.58
	1920	3.364	5.395	2.031	.603	72	46	59	3.6	65	3.08
	Sums	12.642	18.350	5.708	......	......	......	......	......	......	......
	Average	3.160	4.588	1.427	.450	......	......	......	4.1	67	......

[1] The percentage this difference is of the amount of the evaporation in the Briggs pan.

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[1] Presented before American Meterological Society at Chicago, Dec. 29, 1920.

[2] This ratio of Weather Bureau pan to Briggs pan agrees very closely with theory, as is shown by a calculation based upon the results of Jefferies, that the rate of total evaporation from surfaces of the same shape and same orientation to the wind are to each other as the three-quarter powers of their respective areas. Such a calculation shows that the ratio of Weather Bureau pan to Briggs pan should be 0.67. Thus allowing for the effect of the difference of exposure, which, as the author shows, should cause the Weather Bureau pan to evaporate at a slightly greater rate than the Briggs, it appears that the agreement of these observations with theory is very good.—*W. J. H.*

NOTES, ABSTRACTS, AND REVIEWS.

JAPANESE WEEKLY WEATHER REPORT.

The Weather Bureau is in receipt of copies of the first publication to be issued from the newly established Imperial Maine Observatory at Kobe, Japan.[1] This is a Weekly Weather Report, printed in English, containing a series of daily weather maps and a synopsis of weather conditions for the week covered by the report. Tables contain values for atmospheric pressure, air temperature, and precipitation for 14 selected stations, as follows: Maoka, Changchun, Nemuro, Tairen, Niigata, Zinsen (Chemulpo), Tsingtau, Tokyo, Kobe, Nagasaki, Shanghai, Chichishima (Bonin Islands), Nafa, and Taihoku. There is also a table containing the results of pilot balloon observations made at Kobe.

The first report, that for November 1-6, 1920, contains the following introductory statement:

With this issue begins a series of our periodical publications under the title of Weekly Weather Report. Our Daily Weather Chart is prepared with professedly imperfect data in order to meet the pressing demand of the public as quickly as possible. Hence there exists an uncertainty as to the forms of isobars as well as to the positions of the cyclonic centers in those portions of our area wherefrom the telegraphic reports come too late. It seems therefore advisable to correct or improve our Daily Weather Charts after the full data are at hand, and to publish their weekly edition, printing the morning charts of the seven days of the week in one sheet, so as to make the general survey of the sequence of our weather possible. In this weekly report are given the weather charts of 6 a. m. for the days of the week, and a chart of tracks of the cyclonic centers that passed over our area during the period. The isobars are drawn with telegraphic reports from the 59 stations at home and abroad, of which only 29 are given on this printed chart, so as to avoid unnecessary confusion. On the chart showing the tracks of cyclonic centers a small circle represents the position of the center of storm at 6 a. m. of the date specified by the numbers printed near the circle. On the back side of the report are given a general summary of the weather conditions which prevailed during the week and a short description of the atmospheric disturbances.

There are also given the direction and speed of the upper air currents observed by means of pilot balloons at Kobe. For the 14 selected stations are given the barometric pressure reduced to sea level and to standard gravity, air temperature in centigrade degrees, and the amount of precipitation for the past 24 hours.

This new Japanese report forms a valuable addition to the group of publications dealing with weather of the Far East.—*F. G. T.*

RETIREMENT OF PROF. K. NAKAMURA.

[Reprinted from *The Meteorological Magazine*, London, December, 1920, p. 258.]

Prof. K. Nakamura will retire from the direction of the Central Meteorological Observatory of Japan on December 31 of this year [1920]. Prof. T. Okada has been selected for appointment as his successor. Prof. Okada is the author of many contributions to meteorological literature, most of which have appeared in the Journal of the Meteorological Society of Japan.

MONTHLY WEATHER CHARTS ISSUED BY THE CANADIAN METEOROLOGICAL SERVICE.

[Reprinted from *Nature*, London, Dec. 16, 1920, p. 513.]

The Meteorological Service of the Dominion of Canada is issuing a series of monthly weather charts. Each chart shows the mean temperature, the difference from the average mean temperature, and the total precipitation of the month throughout southern Canada. The highest and lowest temperaures at various stations are given in tabular form. Weather and agricultural reports for nearly 100 stations are added. There are also notes on the probability of gales on the Great Lakes in the month of publication.

[1] Cf. Mo. WEATHER REV., Oct., 1920, 48: 598.

AMERICAN METEOROLOGICAL SOCIETY MEETING AT CHICAGO.

The first annual meeting of the American Meteorological Society was held with the American Association for the Advancement of Science at Chicago, December 28-30, 1920. The first session held on the morning of December 28, consisted largely of papers on aerological work and the applicaton of meteorology to aeronautics; the afternoon session dealt principally with weather forecasting. On the morning of the 29th, the business meeting was held; and in the afternoon was the presidential address of Prof. Robert DeC. Ward, who, at the morning session, had been reelected president for 1921. Prof. Ward's address was entitled "Climate and health, with special reference to the United States." Following this address, there was an hour of discussion on the subject of the physiological aspects of meteorology, followed by a short group of papers on instruments and observations. The session on the morning of the 30th was held jointly with the Association of American Geographers. All of the sessions were held in Rosenwald Hall, University of Chicago. In this building is located the University of Chicago station of the Weather Bureau, one of the most fully equipped meteorological stations in the United States. Many visited this observatory on the morning of the 30th, and at other times during the meeting.

Since the organization meeting in St. Louis in December, 1919, two other meetings of the society have been held, one at New York on January 3, 1920, and another at Washington, April 22. The membership increased by about 400 during the year, making a total at present of approximately 1,000.

This and other issues of the REVIEW contain or will include most of the papers or abstracts of papers given at the meeting.

THE SIGNAL CORPS METEOROLOGICAL SERVICE.

The Annual Report of the Chief Signal Officer of the Army for 1920 contains (pp. 57-59) a short discussion of the status and work of the meteorological section of the Signal Corps. The principal discussion of the report concerns itself with the recommendation for a unified meteorological service in the Army. The maintenance of such services by the several branches of the Army would from any point of view, lead to a duplication of work, while the installation of a single station at an artillery range or other place where such data are required would insure ample data for all the services involved.

Other points made in the report show the change of the Signal Corps service between July 1, 1919, and July 1, 1920, from 11 field stations with 11 officers and 49 enlisted men to 15 field stations with 4 officers, 62 enlisted men and 3 civilians. It is mentioned that complete and satisfactory cooperation was maintained between the United States Weather Bureau and the Signal Corps meteorological service, with a result mutually helpful in the collection and interpretation of meteorological data.—*C. L. M.*

THE AUSTRIAN METEOROLOGICAL SERVICE.

The following letter was recently received at the central office of the United States Weather Bureau:

[Translation.]

ZENTRALANSTALT FÜR METEOROLOGIE AND GEODYNAMIK, WIEN XIX. HOHE WARTE 38.

WIEN, am 2. *Dezember, 1920.*

The Zentralanstalt für Meteorologie und Geodyn amik in Vienna is one of the oldest meteorological institutions in the world. Upon the suggestion of the Vienna Academy of Sciences it was founded in the year 1851 by the Austrian State to cultivate meteorology and terrestrial magnetism, and has served science as well as practical life for 70 years.

The results of the war and the subsequent peace now place its further activities in question. The impoverished little Austrian Republic lacks the means which are requisite for carrying on the work of the Zentralanstalt.

The undersigned, the former and the present director of this old institution, feel bound to notify the meteorological institutes, societies, and scientists of the world, which stand in relation, on account of scientific or practical interests, with the Zentralanstalt in Vienna and exchange publications with it, of the urgent distress of the institution.

They proceed for that purpose on the supposition that a scientific institution like the Zentralanstalt is, to a certain degree, the property of all cultivated nations of the world, and all are interested in its existence.

The undersigned, in view of these considerations, are making a plea for funds with which to maintain the Zentralanstalt. The low value of the Austrian crown (a little less than 2 Swiss centimes) makes it on the one hand, easy for foreign countries to help, but on the other hand, makes the endowment, provided by our own State, although it has been increased, seem more and more inadequate.

From now on it is impossible for the Zentralanstalt to publish its yearbooks, even for diminished Austria, although the yearly expenses of printing to-day amount to only 1,000 Swiss francs. The yearbook on account of the results of observations, and other information which they contain, furnish the basis for the development of our science.

In other respects, also, the Zentralanstalt can not possibly maintain its work. The purchase of instruments has become impossible, the hydrogen for pilot balloons, and the rubber balloons for sounding-balloon ascents, are too dear; also the library can not be supplied, as the smallest foreign books or journals cost hundreds of crowns. Consequently the foreign works on meteorology can not be studied and we remain behind the times. The weather map can still be issued a half-year longer, until the stock of paper is exhausted, then that must also cease. The earthquake station in Vienna is still maintained with difficulty, the stations in Graz and Innsbruck must, on the contrary, be discontinued, as the expenses are too great. It is out of the question to resume the observations in terrestrial magnetism which before the war were registered at the high station on the Obir. Wherever one looks, everywhere there prevails the same wretched collapse of our work.

The undersigned refrain from mentioning the rôle which the Austrian school of meteorology has played in the last 50 years. They permit themselves only to name some books which have been issued from the Vienna Zentralanstalt:

Meteorologische Zeitschrift, since 1866; J. Hann, Handbuch der Klimatologie; J. Hann, Lehrbuch der Meteorologie; J. M. Pernter, Meteorologische Optik; W. Trabert, Lehrbuch der kosmischen Physik; F. M. Exner, Dynamische Meteorologie.

May our foreign colleagues be reminded by these book titles of the Zentralanstalt für Meteorologie in Vienna, and assist in its preservation.

Most respectfully,

F. M. EXNER,
The Present Director.
J. HANN,
The Former Director.

SYSTEMATIC PHOTOGRAPHY OF THE AURORA.

[Reprinted from *Scientific American*, New York, Jan. 15, 1921, p. 43.]

The work of Prof. Carl Störmer, in Norway, in making simultaneous photographs of the aurora at two or more stations in order to determine its exact altitude and position in space has now developed to such an extent that, during the remarkable display of March 22-23, 1920, seven stations connected by telephone were in operation: viz, Bygdo (Störmer's home), Oscarsborg, Horten, Christiania, Konigsberg, Fredrikashald, and Dombaas. The distances between stations range from 26 to 80 kilometers. During the years 1911-1920 the stations at Christiania and Bygdo have made more than 300 successful pairs of simultaneous pictures, besides about 200 single pictures. Many fine photographs—single, double, and triple—were secured of the aurora above mentioned. Several single photographs were made of some wonderful blue rays, which formed a "corona" of dazzling brilliancy, and which were so intense that they were photographed, with an exposure of less than a second, after the dawn had so far advanced that first-magnitude stars were barely visible. Prof. Störmer reports that preliminary measurements of his photogrammetric pictures indicate, for the upper limit of the auroral rays in the recent display, an altitude of the order of 500 kilometers (310 miles). No aurora had previously been photographed above about 300 kilometers (186 miles).

REPORT ON THE ASTROPHYSICAL OBSERVATORY FOR THE YEAR ENDING JUNE 30, 1920.

By C. G. ABBOT, Director.

[Reprinted from the Smithsonian Report for 1920, pp. 90-95.]

Seldom is so much of scientific interest included in six pages of an annual report as is to be found in the above. For example, there is a paragraph on "Agreement of Mount Wilson and Chilean Work," and another on "Solar variation confirmed by observations of Saturn." In the discussion of this latter, two hypotheses are advanced relative to the nature of solar variation: (1) "The sun might vary in such a manner that its changes would be observed simultaneously in all directions and so would occur on identical days on all the planets." (2) "On the other hand, the solar radiation may be unequal in different directions."

These irregularities are attributed to unequal absorption or scattering of the rays in the coronal regions near the sun. Or to state it in another way, clouds that absorb or diffuse the solar rays by varying amounts are continually passing in the coronal regions between us and the radiating surface of the sun. The latter may therefore alternately present to us a surface that is relatively clear and hot or clouded and cool. It is only by accepting this second hypothesis that the variations observed in the solar constant and in the brightness of Saturn can be made to synchronize.

It is a matter of regret that volume IV of the Annals of the Observatory, which contains details of what is here merely mentioned, awaits the appropriation of funds for its publication.

There is also reference to "The honeycomb pyranometer," an instrument of the black-body type, for measuring the so-called "nocturnal radiation," and to experiments on the constant of radiation, "sigma."

Finally, the steps are narrated that have made it possible to move the Chilean observing station from a plain near Calama to a near-by mountain site, and to establish a new observatory in the Harqua Hala Mountains, near Wenden, Ariz. Again it is a matter of regret that insufficient funds render the maintenance of these two important observations possible only at great personal sacrifice on the part of Dr. Abbot and his assistants, sacrifices that few are willing to make except under the stimulus of anticipated important achievements.

Dr. Abbot's summary of his report follows:

The year has been marked by the practical completion for publication of Volume IV of the Annals, but no appropriation is yet available for its publication. Close agreement of solar variation was found for 1918 and 1919 between results of Mount Wilson, Calif., and Calama, Chile, 4,000 miles apart. A further remarkable confirmation of the solar variation comes from a comparison of Smithsonian observations in Chile with photoelectric observations of the brightness of Saturn by Dr. Guthnick, of the Berlin-Babelsberg Observatory. This comparison indicates that the nature of the rapid solar variation consists in the rotation with the sun of rays of unequal brightness which strike the different planets successively in the order of their longitudes and fall one after the other upon the earth as the sun by rotation brings them into line with us. A new nocturnal radiation instrument, provisionally called the "honeycomb pyranometer" on account of its cellular structure, and which employs the well-known hollow chamber principle of the "absolutely black" body, but without loss of sensitiveness, has been successfully constructed and tried. By the generosity of Mr. John A. Roebling, of New Jersey, it has been possible to remove the Chile station to a mountain above the dust and smoke of its former plateau location, and also to erect a building on the Harqua Hala Mountain, in Arizona, to which the Mount Wilson solar-constant work will be removed in September, 1920.—*H. H. K.*

DEGREE OF TEMPERATURE TO WHICH SOILS CAN BE COOLED WITHOUT FREEZING.

By GEORGE BOUYOUCOS.

[Abstracted from *Journal of Agricultural Research*, Nov. 15, 1920, Vol. XX, No. 4, pp. 267-269.]

Careful tests showed that soil will not freeze at a temperature of −1° C. (30.2° F.) unless it is vigorously agitated. If not disturbed, it will remain at this temperature indefinitely without freezing.

Dr. Bouyoucos found further that, if not disturbed, sand, loam, and clay soils may be cooled to −4.2° C. (24.4° F.), and peat and muck to −5° C. (23° F.) without freezing. The moisture content of the soils had no influence on the possible extent of supercooling.

This explains why the soil need not be frozen even though the temperature of the air and of the soil itself may be considerably below 32° F.

The author points out that by the method now in vogue for measuring the temperature of soils during cold weather the thermometer may give a record several degrees below the freezing point and yet the soils may not be actually frozen.

"Indeed," he says, "the ability of soils to resist freezing even when their temperature is much below the freezing point throws considerable new light on questions regarding the temperature of soils in cold seasons and consequently upon the physical, chemical, and bacteriological processes going on in the soils during those seasons."—*J. Warren Smith.*

CLIMATE OF NEW ZEALAND.[1]

By Lieut. Col. D. C. BATES, Dominion Meteorologist.

[Review.]

This useful book [2] gives averages of temperatures, rainfall, and, in some cases, sunshine, for 11 stations in New Zealand, ranging from Auckland in the north, with a superb subtropical climate, to Invercargill in the south with the climate of southwest England. The climatic features of each district are succinctly described, but we miss the generalized account of the meteorology of the region which would bind the sections together and enable the reader to see how far the local characteristics are subservient to the prevailing winds and other far-reaching causes.

[1] Reprinted from *The Meteorological Magazine*, London, December, 1920, p. 257.)
[2] Prepared for publication in the *New Zealand Official Year-Book.*

INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE GROWTH OF PSEUDOMONAS CITRI AND ITS HOST PLANTS AND ON INFECTION AND DEVELOPMENT OF THE DISEASE.

By GEORGE L. PELTIER.

[Abstracted from *Journal of Agricultural Research*, Dec. 15, 1920, Vol. XX, No. 6, pp. 447-506.]

This is a complete and valuable study, not only of the effect of temperature and humidity on the development of citrus diseases, but on the growth and development of the different citrus trees.

Two types of rest periods are discussed: Winter dormancy, brought about by the approach of cold weather when cell activity ceases to a great extent, and the short rest periods which occur during the growing season when some of the cell functions merely slow up.

With the time factor included, the optimum temperature for citrus plants lies between 20° and 30° C. (68° and 86° F.).

Three conditions are essential for disease infection—the presence of free moisture on the plant, a suitable temperature, and an actively growing plant.

The conditions for the most rapid development of citrus diseases are also those that are most favorable for the growth of the host plants.

This study, with another that Dr. Peltier is now making on the relations of climate to citrus canker and scab, will make a valuable addition to our at present rather incomplete knowledge of the effect of climate and weather on plant diseases.—*J. Warren Smith.*

CITRUS FRUIT FUMIGATION SAFEST IN DARK AND AT MODERATE TEMPERATURES.

While it has long been known that the presence of light during fumigation of citrus fruit with hydrocyanic acid is one of the factors which causes injury to both fruit and foliage, it has not been known that light before and after fumigation has a similar effect. This fact has been disclosed by recent tests conducted in California by specialists of the United States Department of Agriculture, who have made a report of the experiments with suggestions for preventing injury, in department Bulletin 907, "Fumigation of Citrus Plants with Hydrocyanic Acid: Conditions Influencing Injury."

Moisture and temperature, as well as light, influence fumigation injury, and experiments show that fumigation is more safely performed at temperatures below 80° F. Sudden changes of temperature over a wide range during exposure tend greatly to increase plant injury. Trees in wet soil are likely to be more severely injured than healthy trees in dry soil.

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C. F. TALMAN, Professor in Charge of Library.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1920.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations Section, Washington, Feb. 2, 1921.]

For a description of instruments and exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48:225.

From Table 1 it is seen that there were but few days with clear skies at any of the stations, and the solar radiation intensities measured averaged slightly below the normal for December.

Table 2 shows a deficiency in the radiation received from the sun and sky at all three stations, although least marked at Lincoln.

For the year, Washington shows a deficiency of about 1.3 per cent of the normal, which, however, was all accumulated in the months of November and December. Madison shows almost no departure for the year, although most of the time after June 1 there was considerable excess.

A skylight polarization measurement of 71 per cent on the 16th was the only measurement made at Madison during the month. At Washington measurements of 59 per cent on the 18th, and 60 per cent on the 28th were the only two measurements obtained.

TABLE 1.—*Solar radiation intensities during December, 1920.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	Air mass: 75th meridian time.	A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Dec. 8	2.87			1.09		1.43					3.15
15	4.17	0.90	1.01	1.15		1.47					2.62
17	3.45				1.13						3.45
18	2 36		0.85	0.98							1.68
28	2.87	0.63	0.80	0.96	1.22						2.36
31	4.17				1.18						4.75
Means		(0.76)	0.89	1.04	1.18						
Departures		±0.00	±0.00	−0.01	−0.04						

Madison, Wis.

Date.	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon.
Dec. 7	2.87	0.91	1.03								3.81
16	2.26	1.06	1.16								2.87
27	1.19								0.73		1.19
Means		(0.98)	(1.10)						(0.73)		
Departures		+0.05	−0.03						−0.34		

TABLE 1.—*Solar radiation intensities during December, 1920*—Contd.

Lincoln, Nebr.

Date.	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	Air mass: 75th meridian time.	A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal	mm.
Dec. 4	3.99		1.08	1.21	1.36				1.05	0.89	4.57
14	3.45			1.17							3.15
15	2.87	1.08	1.15	1.27				1.23	1.11	1.00	2.36
16	2.62							1.13	0.81		3.00
27	0.66								1.19		0.86
30	2.74			0.96							5.56
31	4.75		0.99	1.18							7.04
Means		(1.08)	1.07	1.16	(1.36)			(1.18)	1.04	(0.94)	
Departures		+0.18	+0.02	−0.06	−0.03			−0.02	−0.04	−0.03	

Santa Fe, N. Mex.

Date.	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon.
Dec. 4	2.06					1.73	1.53	1.32	1.22	1.13	2.36
8	2.26							1.22			2.26
13	1.45		1.31	1.35							1.37
14	1.96		1.16	1.29	1.44	1.57					2.36
15	1.37		1.26								2.26
18	2.36				1.46						2.87
29	1.96	1.03	1.30	1.39							2.26
30	1.96		1.31		1.55			1.30	1.24		2.87
Means		(1.03)	1.27	1.34	1.48		(1.53)	1.28	(1.23)	(1.13)	
Departures		−0.11	+0.02	−0.02	−0.02		+0.05	−0.02	+0.02	+0.06	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning—	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 3	142	113	130	−17	−12	−43	− 898	+558	
10	113	90	180	−41	−35	+ 8	−1,185	+311	
17	114	103	149	−40	−26	−23	−1,466	+131	
24	139	130	193	−16	− 5	+17	−1,594	+ 89	

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, Jan. 30, 1921.]

In continuation of preceding publications, I give in the following table the results obtained at the Montezuma station, Calama, Chile, in November, 1920, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

The transmission coefficient at 0.5 micron is not given for November 25, 26, and 27, due to the fact that not all of the data for these days have been received. No observations were made on the 28th and 29th owing to cloudiness, and the values for the 30th have not been computed.

Date.	Solar constant.	Method.	Grade	Transmission coefficient at 0.5 micron.	Humidity. ρ/ρ s. c.	Humidity. V. P.	Humidity. Rel. hum.	Remarks.
1920.								
A. M.	*cal.*					*cm.*	*P. ct.*	
Nov. 1	1.963	E_0	VG+	0.859	0.504	0.36	42	
2	1.958	M_2	S	.875	.641	.19	14	
	1.953	$M_{1.5}$						
	1.956	W. M						
3	1.951	$M_{2.5}$	S	.872	.616	.22	23	Few clouds low in east.
	1.960	M_2						
	1.956	W. M						
4	1.957	M_3	S−	.861	.521	.27	34	
	1.938	$M_{2.5}$						
	1.952	W. M						
5	1.974	E_0	VG+	.868	.660	.17	18	
	1.946	$M_{2.5}$						
	1.936	M_2						
	1.951	$M_{1.5}$						
	1.950	W. M						
6	1.940	$M_{2.5}$	S	.878	.697	.15	12	
	1.950	M_2						
	1.955	$M_{1.6}$						
	1.948	W. M						
7	1.952	M_3	S−	.875	.660	.19	16	
	1.941	$M_{2.6}$						
	1.945	W. M						
8	1.951	$M_{2.5}$	S	.873	.640	.19	18	
	1.949	M_2						
	1.950	W. M						
9	1.948	$M_{2.6}$	S	.873	.656	.23	17	
	1.947	M_2						
	1.944	$M_{1.5}$						
	1.947	W. M						
10	1.953	$M_{2.25}$	S−	.872	.656	.22	15	Small patches of cirrus scattered about sky.
	1.953	M_2						
	1.940	$M_{1.45}$						
	1.949	W. M						
11	1.956	$M_{2.19}$	S	.872	.675	.20	15	
	1.955	M_2						
	1.952	$M_{1.5}$						
	1 955	W. M						
Nov. 12	1.928	M_3	S−	0.872	0.598	0.19	20	
	1.944	$M_{2.5}$						
	1.938	W. M						
13	1.950	E_0	E+	.872	.617	.23	20	
	1.950	M_3						
	1.949	M_2						
	1.952	$M_{1.5}$						
	1.950	W.M.						
14	1.938	$M_{1.56}$	S	.858	.665	.28	21	Cirri scattered about sky.
	1.946	$M_{1.46}$						
	1.942	W. M						
15	1.964	E_0	E−	.850	.538	.24	25	Some cirri in east.
P. M.								
16	1.918	$M_{2.5}$	S−	.854	.462	.37	25	Cirri scattered about sky. None near sun.
	1.929	M_2						
	1.925	W. M						
17	1.966	$M_{1.01}$+	S−	.859	.688	.34	18	Cirri in north and east, preventing earlier observations.
	1.962	$M_{1.01}$−						
A. M.								
18	1.964	W. M						Cirri prevented long method.
	1.947	M_3	S	.866	.485	.28	31	
	1.941	$M_{2.5}$						
	1.936	M_2						
	1.942	W. M						
P. M.								
21	1.957	$M_{1.43}$	S−	.875	.818	.18	8	Clouds scattered aroun sky. None near sun.
A. M.								
22	1.928	M_2	S−	.874	.667	.33	26	Low clouds in east preventing earlier observations.
	1.953	$M_{1.5}$						
	1.945	W. M						
23	1.955	$M_{1.5}$	S	.874	.747	.27	17	Patches of cirrus scattered about sky.
	1.958	$M_{1.46}$						
	1.956	W. M						
24	1.937	M_3	S	.875	.656	.17	18	
	1.931	$M_{2.5}$						
	1.935	W. M						
P. M.								
25	1.939	$M_{2.12}$	S−		.690	.23	11	
	1.953	M_2						
	1.949	W. M						
A. M.								
26	1.939	M_3	S−		.702	.20	18	
	1.935	$M_{2.5}$						
	1.938	W. M						
27	1.935	$M_{2.19}$	S−		.667	.26	19	
	1.939	M_2						
	1.938	W. M						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was considerably below the normal at land stations on the American coast, from Newfoundland to Georgia as well as in the Azores, while it was slightly below on the northern shore of the Gulf of Mexico, in the Bermudas and in the greater part of the British Isles; it was higher than usual on the north coast of Scotland, and slightly above the normal in the West Indies.

December is considered the stormiest month of the year on the North Atlantic, and the month under discussion was no exception to the general rule, although the number of days in which winds of gale force were reported in the steamer lanes was not far from the normal, as shown on the pilot chart; they were somewhat more frequent than usual between the 35th and 40th parallels, west of the 50th meridian.

Very few reports of fog were received from vessels, although it was observed frequently at land stations in England and Scotland.

On December 1 there was a severe disturbance central near latitude 35° N., longitude 36° W., and the observer on the British S. S. *Idaho* states that from 8 p. m. on the 1st to 8 a. m. on the 2d his vessel experienced north easterly gales that at times increased to hurricane force with heavy seas and rain squalls. The lowest barometer reading was 29.77 inches at midnight of the 1st; position, latitude 38° 03′ N., longitude 41° 44′ W. On the 1st there was also a disturbance about 300 miles west of the Irish coast, as shown by the storm log of the Danish S. S. *Oscar II*, which follows:

Gale began on November 30. Lowest barometer 28.51 inches at 8 p. m. on the 30th; position, latitude 57° 35′ N., longitude, 17° 20′ W. End of gale on December 3. Highest force of wind, 10; shifts of wind near time of lowest barometer, SW-WSW.

On the 2d a low was central near Halifax, N. S., and strong westerly gales swept the American coast between the 30th and 45th parallels. Storm logs are as follows:

West Isleta, American S. S.:

Gale began on the 1st. Lowest barometer 29.14 inches at 4 p. m. on the 2d; position, latitude, 42° 34′ N., longitude, 61° 25′ W. End of gale on the 3d. Highest force of wind, 10; shifts of wind near time of lowest barometer, W.-SSW.-S.-W.-WSW.-WNW.-NW.-WNW.-W.

Steelmaker, American S. S.:

Gale began on the 2d. Lowest barometer 30.16 inches at 3 a. m. on the 2d; position, latitude, 29° 50′ N., longitude, 74° 15′ W. End of gale 11 a. m. on the 2d. Highest force of wind, 8; shifts not given.

As shown on Chart IX for December 3, this disturbance moved but little during the next 24 hours, with northerly gales in the western quadrants and southerly in the eastern.

Unusually heavy weather was experienced by one vessel in tropical waters as seen by the storm log from the American S. S. *Point Bonita*:

Lowest barometer 29.74 inches at 10:30 a. m. November 30. Gale began on November 30; position, latitude 9° 30′ N., longitude 79° 55′ W. End of gale December 4. Highest force of wind 8, steady from northeast.

On the 4th the center of the northern disturbance was near latitude 50°, longitude 40°, and winds of gale force prevailed over the middle section of the steamer lanes, as well as in the vicinity of the Irish Channel and French coast.

From the 5th to the 7th no unusual conditions existed, although a few vessels in northern waters reported moderate to strong gales.

On the 8th and 9th moderate to strong northwesterly to westerly gales were encountered over the region between the coasts of Spain and Portugal and the 20th meridian. Storm logs:

Giuseppe Verdi, Italian S. S.:

Gale began on the 8th. Lowest barometer 29.54 inches at 8 p. m. on the 8th. Position, latitude 35° 58′ N., longitude 12° 03′ W. End of gale on the 9th. Highest force of wind, 9; shifts not given.

Westmoreland, American S. S.:

Gale began on the 8th. Lowest barometer 29.56 inches at 6 p. m. on the 8th; position, 35° 58′ N., longitude 6° 30′ W. End of gale on the 10th. Highest force of wind, 9; shifts SW.-NW.

Shortly after the Greenwich Mean Noon observation on the 8th a severe disturbance of limited extent developed in the vicinity of Cape Hatteras. Storm logs:

Radiant, American S. S.:

Gale began on the 8th. Lowest barometer 29.66 inches at 10 a. m. on the 8th. Position, latitude 34° 31′ N., longitude 76° 06′ W. End of gale on the 9th. Highest force of wind, 9; shifts not given.

Manchester Port, British S. S.:

Gale began on the 9th. Lowest barometer 29.65 inches at 7 a. m. on the 9th; position, latitude 37° 20′ N., longitude 73° 34′ W. End of gale on the 9th. Highest force of wind, 10; shifts not given.

This LOW drifted slowly northward along the American coast, and on the 11th the center was near Halifax, N. S. A few vessels a short distance north of Bermuda encountered moderate to strong gales on both the 10th and 11th, although the storm area was of limited extent.

On the 9th and 10th a severe disturbance covered a large area over the central portion of the steamer lanes, although not enough observations were received to determine its northern limits. Storm logs follow:

Swazi, British S. S.:

Gale began on the 9th. Lowest barometer 28.83 inches at 9 p. m. on the 9th. Position, latitude 54° 05′ N., longitude, 29° 26′ W. End of gale on the 11th. Highest force of wind 9; shifts, SSW.-WNW.

Kerowlee, American S. S.:

Gale began on the 9th. Lowest barometer 29.42 inches at 5 a. m. on the 9th. Position, latitude 47° 45′ N., longitude 41° 15′ W. End of gale on the 10th. Highest force of wind, 10; shifts of wind N.-NW.

Bardic, British S. S.:

Gale began on the 7th. Lowest barometer 29.57 inches at noon on the 10th. Position, latitude, 49° 30′ N., longitude, 30° 21′ W. End of gale on the 11th. Highest force of wind 10; steady from SW.

On the 13th there was a LOW central about 300 miles east of St. Johns, N. F. that moved slowly eastward with a comparatively uniform rate of speed, and on the 17th the center was near latitude 50°, longitude 25°. On the 13th and 14th northeasterly gales prevailed between the coast of Newfoundland and the 45th meridian, and on the 15th and 16th only a few gale reports were received from vessels in widely scattered positions, while on the 17th moderate gales prevailed near the center, as shown on Chart X.

At Greenwich Mean Noon on the 17th a number of vessels in the 5-degree square south of St. John's, N. F., reported moderate easterly winds that afterwards de-

veloped into a severe disturbance which moved rapidly eastward, as on the morning of the 18th the center was near latitude 50°, longitude 40°. A large number of special reports were received from vessels regarding this storm which was of a most unusual nature in many respects. Some of the storm logs and reports are as follows:

Nieuw Amsterdam, Dutch S. S.:

Gale began on the 17th. Lowest barometer 28.56 inches at noon on the 17th. Position, latitude 43° 18′ N., longitude, 55° 18′ W. End of gale on the 17th. Highest force of wind, 12; shifts ENE.-NNW.

At 12.05 p. m. on the 17th, wind reached hurricane force, holding for half an hour, barometer rising, and within 10 minutes there was an extraordinary high sea and swell. Diminishing wind and swell in the evening; rain showers and lightning in the southwest.

Osawatomie, American S. S.:

Gale began 17th. Lowest barometer 28.35 inches at 2:35 p. m. on the 17th. Position, latitude 43° 43′ N., longitude 53° 40′ W. End of gale 11 a. m. on the 18th. Highest force 11; shifts SW.-W.-WNW.-NW.

At noon on the 17th, barometer read 28.58 inches; the weather was foggy with wind south, force 4. At 1 p. m. A. T. S. wind became west, force 6, for about 20 minutes; barometer rapidly falling all the time. The wind then shifted back to SW., 6, until 2:35 p. m., when it became WNW., 12, lasting for about an hour, the barometer rising rapidly in the meanwhile. At 9 a. m. on the 18th wind was SW. and began hauling toward the NW.; similar to that of the 17th but of slightly less violence and did not last so long; barometer then began to rise slowly. Sky covered with cirrus veil. Position, Greenwich Mean Noon December 18, latitude 43° 05′ N., longitude 56° 04′ W.

Mongolian Prince, British S. S.:

At noon December 17, wind WSW., 3, barometer 29.67 inches, position, latitude 47° 24′, longitude 38° 20′ W. 3 p. m., S. 3; 29.63 inches. 5 p. m. SSE., 4; 29.59 inches; 9 p. m.; SW., 9; 29.17 inches, terrific squalls. Midnight, SW., 12; 29.25 inches; hurricane. December 18, 3 a. m. W., 12, 29.31 inches; 8 a. m. W. by N., 12; 29.53 inches. Noon, W. by N., 9; 29.62 inches; 19th, 1 a. m. NW. squally, heavy rain, weather moderating.

On the 17th strong westerly gales were encountered off Hatteras, and on the 16th and 17th one vessel reported similar conditions in the Gulf of Mexico. Storm logs are as follows:

Hartford, American S. S.:

Gale began on the 15th. Lowest barometer 30.07 inches at noon on the 17th; position, latitude 30° 11′ N., longitude, 88° W. Gale continued until ship entered Mobile Bay on the 17th. Highest force of wind, 8; no shifts given.

W. M. Burton, American S. S.:

Gale began on the 17th. Lowest barometer 29.54 inches at 10:30 a. m. on the 17th; position, latitude 34° 58′ N., longitude 73° 29′ W. End of gale on the 18th. Highest force of wind 12; shifts not given.

On the 20th a moderate disturbance was central near latitude 50, longitude 22, that developed into one of considerable force 24 hours later, when the center was near the north coast of Ireland. Storm logs follow:

Scythian, British S. S.:

Gale began on the 20th. Lowest barometer 28.93 inches at 11 p. m. on the 21st; position, latitude 50° 24′ N., longitude 19° W. End of gale on the 22d. Highest force of wind, 10; shifts, SW.-W.-NW.

Eglantier, Belgian S. S.:

Gale began on the 21st. Lowest barometer 29.19 inches on the 21st; position, latitude 49° 43′ N., longitude 7° 29′ W. End of gale on the 23d. Highest force of wind, 10; shifts S.-WSW.-W.

On the 22d and 23d unusually heavy weather prevailed in the region between the Azores and the Bermudas, the storm area extending as far south as the 30th parallel. Storm logs:

Oranian, British S. S.:

Gale began on the 22d. Lowest barometer 29.40 inches at 1 a. m. on the 23d; position, latitude 36° 30′ N., longitude, 32° 10′ W. End of gale on the 28th. Highest force of wind, 9. Wind varying between WNW. and WSW. Very heavy squalls during the period between the 22d and 28th. Barometer in these squalls ranging from 29.42 inches to 29.67 inches.

From December 23 to the end of the month the Azores HIGH was replaced by a persistent LOW, the barometer reading at Horta, Azores, ranging from 29.16 inches on the 25th to 29.84 inches on the 29th. This reversal of the normal pressure distribution was responsible for the unusual and unsettled conditions prevailing over the greater part of the ocean during this period.

On the 24th strong southerly gales were encountered in the regions between the Bermudas and the 50th parallel, as shown by the following storm logs:

Jalapa, American S. S.:

Gale began at 4 p. m. on the 23d. Lowest barometer, 29.49 inches at 4 p. m. on the 24th. Position, latitude 37° 20′ N., longitude 16° 35′ W. End of gale at noon on the 28th. Highest force of wind, 10; shifts W. by S.-SW.

Kayseeka, American S. S.:

Gale began on the 23d. Lowest barometer 28.95 inches at 5 a. m. on the 25th. Position, latitude 47° 10′ N., longitude 12° 30′ W. End of gale on the 28th. Highest force of wind, 10; steady from SW.

Charts XI, XII, and XIII show the conditions on the 25th, 26th, and 27th, respectively. Storm logs follow:

Grampian Range, British S. S.:

Gale began on the 25th. Lowest barometer, 28.81 inches at noon on the 27th. Position, latitude 46° 51′ N., longitude 35° 15′ W. End of gale on the 27th. Highest force of wind, 9; steady from NNW.

Inca, British S. S.:

Gale began on the 25th. Lowest barometer, 29.98 inches on the 25th. Position, latitude 38° 42′ N., longitude 63° 25′ W. Highest force of wind, 8; steady from NNW.

Edgewood, American S. S.:

A severe gale was encountered on the night of the 27th, and early morning of the 28th, with a heavy cross sea, SW. and NW. It was necessary for the vessel to heave-to. Lowest barometer, 29.57 inches at 10 p. m. on the 27th. Position, latitude 36° 42′ N., longitude 70° 30′ W. Highest force of wind, 10; shifts SW.-NW.

On the 28th and 29th heavy weather was the rule over the greater portion of the steamer lanes, with a well developed LOW central near midocean. Storm logs:

Stanmore, British S. S.:

Gale began on the 28th. Lowest barometer, 28.60 inches at 1 p. m. on the 29th. Position, latitude 46° 22′ N., longitude 40° 06′ W. End of gale on the 30th. Highest force of wind, 12; shifts SW.-W.-S.

Gaasterland, Dutch S. S.:

Gale began on the 29th. Lowest barometer, 28.56 inches at 9:10 p. m. on the 29th. Position, latitude 47° 40′ N. longitude 33° 40′ W. End of gale on the 31st. Highest force of wind, 10; shifts S.-W.

This disturbance remained nearly stationary during the remainder of the month, and reached its greatest intensity on the 30th, as shown by Chart XIV for that date. Storm log:

Eglantier, Belgian S. S.:

Gale began on the 29th. Lowest barometer, 29.58 inches at noon on the 30th. Position, latitude 38° 02′ N., longitude 26° 05′ W. End of gale on the 31st. Highest force of wind, 9; steady from SW.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Over the northern part of the North Pacific Ocean, especially in the Gulf of Alaska, December was a stormy month. Reports from almost all vessels on the northern steamer routes contain references to gales and rough seas. Over the southern part of the ocean; except for a brief period at the beginning of the last decade, fine weather was general.

The most noteworthy feature of the weather of the month was the low pressure and accompanying storm conditions in the vicinity of Midway Island during the last decade. On the 22d an unusually low barometer reading of 29.36 inches was recorded at Midway Island. The lowest on record at Midway Island appears to be 29.28 inches, made on January 28, 1917.

The American aux. sch. *Flaurence Ward* which plies between Honolulu and neighboring islands was just to the eastward of Midway Island during the period when this depression reached its greatest intensity.

According to the report of Capt. Geo. H. Piltz of that vessel conditions became threatening on the 22d. At 4 p. m. on that date the wind was SE., 4, barometer 29.62 inches and falling steadily. At 6:30 p. m. the wind went to S. and at 8 p. m. to SSW., where it remained throughout the entire time of the gale, lasting until midnight of the 24th. The barometer continued to fall until midnight of the 23d when it stood at 29.12 inches, remaining at that point until 4 a. m. of the 24th. The wind increased steadily in force and reached its greatest intensity, force 11, between 8 a. m. and noon of the 24th, or just after the pressure had begun to rise. At the commencement of the storm there was terrific lightning and heavy rain and the weather remained squally until the force of the gale began to abate.

The respective Greenwich Mean Noon positions of the *Flaurence Ward* on the dates mentioned were as follows: 23d, latitude 27° 40′ N., longitude 167° 30′ W.; 23d, latitude 27° 42′ N., longitude 166° 23′ W.; 24th, latitude 27° 55′ N., longitude 163° 51′ W.

This depression occasioned a kona, or southwest, storm at Honolulu from the 22d to the 25th. During this period the wind reached a maximum velocity of 36 miles an hour from the west and an extreme velocity of 42 miles. The rainfall for the same period was 6.21 inches, of which 4.83 inches fell in 24 hours. The total rainfall for the month at Honolulu was 8.72 inches, or considerably more than twice the average amount. The mean temperature was 1.3° above the normal.

Between the 22d and the end of the month pressure was generally low over the northeastern part of the ocean with the center of greatest depression over the Gulf of Alaska. East of the 180th meridian high pressure was confined to the region between the Hawaiian Islands and the American coast.

Vessels on the northern steamer routes during the last decade experienced stormy weather not only as a result of the depression referred to but also on account of one which appeared to be central to the east of Japan on the 28th.

The American S. S. *Mobile City*, Capt. C. H. Longbottom, Shanghai for Seattle (Dec. 22–Jan. 8), experienced strong winds and gales during the entire voyage. On December 30–31, so states Mr. C. Kennedy, the observer, when nearing the 180th meridian, the *Mobile City* encountered a gale of hurricane force accompanied by terrific seas on account of which it was necessary to put about and run before the gale. As it appeared from conditions that the depression was traveling in a northeasterly direction a course was laid to the southward as soon as conditions permitted and the vessel soon ran into fine weather. The lowest barometer observed was 28.69 inches at 4 a. m. of the 31st, when in latitude 48° 35′ N., longitude 178° E.

The Japanese S. S. *Africa Maru*, Capt. H. Yamamoto, Yokohama for Victoria (Dec. 17–30) appears to have been near the center of the depression in the Gulf of Alaska near the close of the month. At 2 a. m. on the 27th, when in latitude 50° 48′ N., longitude 147° 22′ W., the barometer fell to 28.39 inches, accompanied by a whole gale from WSW. and a tremendous sea.

In Asiatic waters several vessels experienced about the 7th heavy weather as a result of depressions on the front of an anticyclone of great magnitude which developed over eastern Siberia.

Storm logs are as follows:

West Ira, American S. S., Capt. C. F. Cross, Yokohama, (Dec. 1), for San Francisco:

Gale began on 8th; lowest barometer 30.03 inches at 8 p. m. of 9th in latitude 39° N., longitude 144° E.; highest force of wind, 9 NW. End of gale, 11th; shifts of wind, WNW., NW.

West Niger, American S. S., Capt. R. L. Holt, Hongkong (Dec. 1), for San Francisco:

Gale began on 7th; lowest barometer 29.54 inches at 4 p. m. of 7th in latitude 31° 30′ N., longitude 137° 50′ E.; highest force of wind, 10, NW.; end of gale on 8th. Shifts of wind NE., E., WSW., NW., W., NW.

West Cadron, American S. S., Capt. F. E. Anderson, Shanghai (Dec. 2), for San Francisco:

Gale began on 7th; lowest barometer, 29.35 inches at 8 p. m. of 7th in latitude 35° 35′ N., longitude 142° 35′ E.; highest force of wind 9, NE.; end of gale on 8th; shifts of wind NE. to NNE.

The closing days of the month saw renewed storm activity on the Asiatic side resulting from a depression which appears to have developed to the east of Japan about the 27th, moving thence northeastward toward the Aleutians. The British S. S. *Empress of Russia*, the Japanese S. S. *Alabama Maru* and *Korea Maru*, and the American S. S. *Mobile City* were all more or less involved in this storm from the 27th to the 31st. The experience of the last-named vessel has already been described.

On the 16th, as a result of the southeastward movement over the western United States and Mexico of an anticyclone of great magnitude fresh to strong easterly winds, reaching gale force at times, were experienced off the west coast of Central America.

The American S. S. *Stanley*, Capt. B. I. Joyce, Panama (Dec. 11) for Honolulu, experienced a gale which began on the 15th and continued until the 17th, the wind throughout being NE. and reaching a force of 10. The lowest barometer was 29.81 inches at 11 p. m. of the 15th in latitude 12° 03′ N., longitude 95° 52′ W.

In connection with the low barometer in the North Pacific Ocean during the last decade of the month attention is invited to the low pressure in the North Atlantic during the same period, which is referred to in the review of the weather for that ocean. The departure from normal pressure at Midway Island from the 21st to 31st, inclusive, was −0.31 inch and at Horta for the same period −0.57 inch.

TYPHOON IN THE WESTERN CAROLINES.

On the morning of December 17, a very severe typhoon swept the Western Carolines, causing great destruction on the Island of Yap. A cablegram to this effect was received by Manila Observatory on the 19th, in which our Filipino observer at Yap stated that the barometric minimum as registered by the barograph was as low as 712.47 mm. (28.05 inches), that hurricane winds blew there from northeast veering to south-southeast, and that the majority of our instruments were destroyed.

The above information was confirmed later by the following cablegram from Tokyo, dated December 20, which appeared in the Manila newspapers on December 22: "A very severe storm has destroyed the majority of the buildings on the Island of Yap. The gale prevailing there on December 16 developed a hurricane strength on the morning of the 17th, unroofing several public structures, including the barracks, Government offices, the native school, the telegraph office, the hotel, and several stores, and severely damaging practically every house."

The typhoon appeared about 300 or 250 miles to the east of the Philippines on December 20, threatening for a while to cross the central part of the archipelago. But fortunately it almost stopped moving on the 21st and finally filled up on the 23d, thus disappearing all danger for the Philippines.—*Rev. José Coronas, S. J., Philippine Weather Bureau.*

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Newfoundland.—St. John's, December 28.—A blizzard swept over this island colony to-day and left confusion among communication mediums in its wake. The damage was not extensive, but all shipping was held to ports, train service was disrupted and roads made impassable.—*New York Times, Dec. 29, 1920.*

Capt. Ole B. Bull, whose ship, the *Bergenfjord*, of the Norwegian-American line, arrived here to-day, reported having passed a number of huge icebergs off Cape Race Saturday morning. A heavy snowstorm Saturday night delayed the steamer's arrival eight hours.—*New York Evening World, Dec. 21, 1920.*

Mexico.—Mexico City, Dec. 30.—Mexico City is surrounded by snowclad hills to-day, following the unusually cold weather of the last few days.—*New York Times, Dec. 31, 1920.*

British Isles.—Outstanding features of the weather in the British Isles during December were the wintry spell which occurred during the second week, and the unusual warmth which set in just before Christmas.

* * * The total rainfall for the month in percentages of the average was, England and Wales, 101; Scotland, 91; Ireland, 97.

* * * In London (Camden Square) the mean temperature was 40.7° F. or 0.6° F. above the average.[1]

Continental Europe.—[During the first half of December] easterly wind and very cold weather, with falls of snow, were prevalent over many parts of the Continent. In Germany, central Europe, and parts of France maximum temperatures remained below freezing point on several days. * * *

After this period, low-pressure areas moved from Iceland to Scandinavia and pressure remained low in the eastern Atlantic over a very large area until the end of the month. Temperatures rose generally over western and central Europe, and for the last week of December mild weather predominated on the Continent, except in northern Scandinavia where severe frosts occurred.[2]

France.—Paris, Dec. 18.—France is suffering from an unusually severe cold wave. Belfort, Bordeaux, and Marseilles report temperatures around 11 degress above zero, Fahrenheit. Several canals in the Midi district have been frozen over, and snow has caused considerable damage in the region of Nice. In this city the cold has been severe for several days.—*Washington Evening Star. Dec. 18 (?), 1920.*

Brest, Dec. 28.—A storm of utmost violence is raging along the western cost of France. The sea is very heavy, even in the roads of Brest harbor, where a vessel was sunk last night.—*New York Evening Mail, Dec. 28, 1920.*

India.—The winter rain has so far been scanty in India.[3]

Japan.—Near the middle of the month a heavy storm occurred at the Japanese naval station at Kure, in which 29 vessels laden with iron and coal sank and several heavy guns were plunged into the sea by a landslide.[3]

Australia.—At the beginning of the month beneficial rain fell in New South Wales generally, but in the second week abnormally heavy rain fell over an extensive area around Sydney, doing great damage to the wheat harvest. The storm was the worst that has been experienced in the State for 70 years; 10 inches of rain was recorded in three days, the average December rainfall being 2.6 inches. The rain was particularly disastrous, coming after a three years' drought.[3]

[1] *The Meteorological Magazine*, Jan., 1921, pp. 286-287.
[2] *ibid*, pp. 287 and 292.
[3] *ibid*, p. 292.

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

Cyclones.—The number of LOWS was much above the average. The Alberta type developed numerous secondaries, particularly Colorado LOWS, which became important storms.

Anticyclones.—High pressure areas were also numerous, the Pacific type predominating.

Tables showing the number of LOWS and HIGHS by types follows:

Lows.

	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
December, 1920...	7.0	1.0	2.0	0.0	6.0	2.0	0.0	2.0	1.0	21.0
Average number, 1892-1912.......	4.3	2.5	0.8	0.3	1.1	2.5	0.2	0.3	0.4	12.4

Highs.

	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain Region.	Hudson Bay.	Total.
December, 1920.................	2.0	6.0	4.0	1.0	3.0	16.0
Average number, 1892-1912....	1.1	1.2	4.7	1.3	0.5	8.8

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, D. C., Feb. 1, 1921.]

PRESSURE AND WINDS.

Low pressure over the North Pacific Ocean during December, 1920, favored the entrance into British Columbia and the extreme northwestern portions of the United States of numerous barometric depressions. These usually lost considerable energy on moving inland, and passed eastward, as a rule, along the northern borders of the United States. On the other hand, the high areas frequently entered the United States from the middle Pacific and to the southward of the LOWS, instead of through the Canadian Northwest, as is usual during a winter month, and pursued their easterly courses south of their normal tracks. As a result of these variations from normal conditions the average pressure for the month was lowest along the Canadian border and highest in the extreme south with a frequent resultant flow of warm air from the south into the more northern districts.

For the month as a whole pressure was below the normal in practically all portions of the United States, and likewise in Canada as far as records disclose. This is an exact reversal of the pressure distribution during the preceding month when the averages were almost wholly above the normal in both countries.

PRINCIPAL STORMS.

On the 1st and 2d a low-pressure area moved from the lower Lakes to New England, increasing greatly in severity as it approached the Atlantic coast, where high winds

prevailed. A second important storm moved from the middle Mississippi Valley during the 4th to 7th attended by general rains, and with high winds from the Great Lakes to New England. Another widespread storm over the central valleys on the morning of the 13th moved to the upper Lakes during the following 24 hours, and developed into a storm of great severity, some unusually low barometer readings being reported, and high winds were general over wide areas.

The last decade had frequent changes in pressure and some of the most widespread storms and cold waves of the month occurred during this period. At the beginning of the decade a storm of wide extent covered the far Southwest and from the 20th to 24th overspread practically all portions of the country from the Rocky Mountains eastward. More or less snow occurred during this period over northern districts, and general rains, heavy in portions of the Gulf States and Ohio Valley, fell to the southward.

From the 26th to 28th an area of low barometric pressure moved from Texas to New England causing general but mostly light snows from the upper Mississippi and lower Ohio Valleys eastward, and moderate to heavy rains over the Gulf and Atlantic Coast States.

The first important high-pressure area of the month approached the middle California coast about the 12th and during the following week drifted slowly eastward over the southern portions of the country. This high area in crossing the Plateau and Rocky Mountain regions brought clear skies and unusual opportunities for night radiation, and the lowest temperatures of the month were recorded over those regions. About the 23d high pressure of the normal winter type moved into the upper Missouri Valley from the British Northwest Provinces and during the following four or five days the coldest weather of the month occurred over nearly all districts from the Rocky Mountains eastward.

The passage of several low-pressure areas across the Great Lakes and their continued movement to the New England coast caused high winds in those regions on the corresponding dates, otherwise there were few damaging storms.

The prevalence of high pressure over the more southern districts favored southerly winds in the Mississippi Valley and Great Plains region as far north as the middle portions of the country. Over other sections east of the Rocky Mountains the winds were mainly from westerly points. In the remaining sections the winds were much diversified.

TEMPERATURE.

During the first half of the month temperature changes were less marked than usual for a winter month and the daily values were mostly above normal, particularly in northern and central districts and over the southern Plains, where the mean temperature for this period averaged from 10 to 15 degrees a day above normal. However, the average temperature for the period was slightly below normal in the east Gulf district and over portions of the lower Mississippi Valley and the far West. Warm weather prevailed in the far Northwest near the middle of the month, but was replaced by considerably cooler weather within the next day or two, and on the 17th killing frosts occurred as far south as central Florida and light frost was observed at Miami. There was a sharp fall in temperature in the middle Atlantic States about the close of the second decade, but moderately warm winter weather prevailed in much of the interior of the country. The third decade opened with much colder weather in the northern Rocky Mountain region, which soon overspread the central and eastern States, and zero temperature extended well into the central portions of the country. However, about the middle of the decade warmer weather overspread the interior districts, and within the next day or two became general from the Mississippi Valley eastward. In the meantime, it became much colder in the trans-Mississippi States, with zero temperature extending southward to northern Kansas. Toward the latter part of the month much colder weather prevailed from the lower Lake region southwestward. with zero temperature in the central portions of Missouri, Illinois, and Indiana, and the line of freezing extended to the Gulf coast.

For the month as a whole the temperature averages were above normal in all sections of the country except in portions of the Southeast, the central and southern Rocky Mountain districts, and the far Southwest. From the upper Mississippi Valley eastward and in the far Northwest, the month averaged from 3 to 6 degrees a day warmer than normal.

During the first two weeks freezing weather did not extend farther south in the Mississippi Valley than to southern Illinois, and temperatures below zero were not observed except in the mountain regions of the West. The latter half of the month was considerably colder, however, especially in the last decade in the northern districts. The lowest temperature observed during the month, $-38°$, occurred in Colorado, but temperatures only a few degrees higher were observed generally in the northern tier of States and in the mountains of the West.

The highest temperatures were observed very generally during the first half of the month, although in portions of Idaho, Nevada, and Oregon the warmest days were the last two of the month.

PRECIPITATION.

In the districts from the Mississippi Valley eastward, precipitation was frequent, and similar conditions existed on the Pacific slope from central California northward. In portions of the Rocky Mountains and generally in the Southwest precipitation was infrequent and the amounts generally light.

For the month as a whole precipitation was heavy in the central Gulf States, along the Atlantic coast, and from central California northward. From 6 to 12 inches of rain occurred from Louisiana eastward to Alabama, while somewhat less amounts were received in portions of North Carolina and New England. Precipitation was less than normal in portions of the Ohio, lower Missouri, and upper Mississippi Valleys, and generally in the Rocky Mountain regions and the Southwest.

SNOWFALL.

Snow occurred over the greater part of the country at some period during the month, and east of the Rocky Mountains the total was near the seasonal average in most sections, although the amounts that remained unmelted for any considerable period were usually less than normal. It was less than normal in the Atlantic Coast States from Virginia to Massachusetts and more than normal in northern New York and extreme upper Michigan; 30 inches were recorded at Oswego, N. Y., and 40 inches at Houghton, Mich. In the mountain districts of the West the snowfall was usually less than the normal, although at the end of the month it had accumulated to

considerable depths in the higher elevations of California, Idaho, and eastern Oregon, but in other districts no considerable amounts had been stored.

RELATIVE HUMIDITY.

The moisture in the atmosphere as disclosed by the average relative humidity shows rather discordant conditions when the indications from near-by stations are compared. No extensive areas had uniformly positive or negative departures from the normal, and large and small departures are frequently shown for stations in close proximity.

In general, the average relative humidity was considerably above normal from the middle Mississippi Valley westward and below to about the same extent in the Gulf States, Appalachian Mountain districts, and in the far Northwest.

STORMS AND WARNINGS—WEATHER AND CROPS.

STORMS AND WEATHER WARNINGS.

Washington Forecast District.—The month was marked by unusual activity in the development and movement of LOWS across the country and by the absence of Alberta HIGHS until near the end of the month. As a consequence storm warnings were required more than the usual number of times and no cold-wave warnings were issued until the 22d, and there were no general cold wave warnings at all during the month. Seven LOWS moved across the country with a central pressure of 29.4 inches or lower at the maximum stage of their development and in three of these storms the pressure fell below 29 inches.

During 11 of the first 15 days of the month storm warnings were displayed either on the Great Lakes or the middle or north Atlantic coast. At 3 p. m. of the 1st a disturbance was central over eastern Pennsylvania, moving northeastward and increasing greatly in intensity, and storm warnings were ordered displayed on the New England coast. These warnings were fully verified.

On the morning of the 4th a disturbance, central over Illinois and moving northeastward, was expected to increase considerably in intensity as it advanced over the Lake region, and warnings were displayed at 10 a. m. on the Great Lakes, except on western Lake Superior and the western shore of Lake Michigan. At 8 p. m. the storm was central over Lake Huron with increasing intensity and storm warnings were ordered displayed on the Maine coast. During the night pressure fell decidedly over the northeastern States and a secondary disturbance developed over southern New York. At 9:30 a. m. of the 5th warnings were displayed from Delaware Breakwater northward to Portsmouth, N. H. The warnings on the Atlantic coast were fully verified and those on the Great Lakes were partially verified.

The next storm warnings were ordered at 2 p. m. of the 8th for the Atlantic coast at and between Cape Hatteras and Delaware Breakwater, as a disturbance then central off the southern North Carolina coast was expected to increase in intensity as it moved northeastward. At 9:30 p. m. the warnings were extended northward to Provincetown, Mass., and the following morning to Eastport, Me. These warnings were fully verified, the highest wind velocity reported being 64 miles an hour from the northeast at Cape Henry, Va.

At 8 p. m. of the 12th a disturbance of marked intensity was central over the middle Missouri Valley, moving northeastward and storm warnings were ordered displayed at 10 p. m. on Lake Superior, northern Lake Huron, and on Lake Michigan, except the extreme southern portion. By the following morning this disturbance had split and had two centers, one over eastern Minnesota and the other over Missouri. The latter became the main storm and increased greatly in intensity and during the afternoon and evening of the 13th the warnings were extended to cover all of the Great Lakes. In addition warnings were ordered displayed on the Atlantic coast from Charleston, S. C., to Eastport, Me., at 10 p. m. This storm increased remarkably in extent and intensity and by the morning of the 14th its central pressure had fallen to 28.60 inches over upper Michigan and gales prevailed generally in middle and northern sections east of the Mississippi River. The winds were controlled by this storm to a great height and a naval balloon which left Rockaway, N. Y., at 12:15 p. m. on the 13th drifted rapidly northward and then north-northwestward to the southern end of James Bay, where it landed at 2 p. m. on the 14th. The center of this storm moved very little during the 14th and 15th and warnings remained displayed on the Great Lakes until the evening of the 15th, when the display of storm warnings for the season terminated. The highest velocities reported were 76 miles an hour from the southwest at Toledo, Ohio, and 72 miles an hour from the south at New York, N. Y. Little damage to shipping was reported as all possible precaution had been taken, due to the timely warnings issued.

On the evening of the 22d a storm of marked intensity was central over Michigan, moving east-northeastward, and storm warnings were ordered for the Atlantic coast from Cape Hatteras to Eastport, Me. On the 23d a velocity of 60 miles an hour from the west was registered at New York, N. Y., which was the only wind of gale force reported on the Atlantic coast. At Buffalo, N. Y., the wind reached a velocity of 96 miles an hour from the southwest, which is the highest ever recorded at that station.

At 10 p. m. of the 26th warnings were ordered displayed on the Atlantic coast from Delaware Breakwater to Eastport, Me., in connection with a disturbance which extended from Michigan southward to the Louisiana coast and with rapidly falling barometer to the eastward. On the 27th warnings were extended southward to Cape Hatteras. Although the pressure continued to fall rapidly no winds of gale force were reported at land stations until the storm center reached the Canadian Maritime Provinces, where gales and heavy snow were general.

Small-craft warnings were displayed on the east Gulf coast from Bay St. Louis, Miss., to Appalachicola, Fla., on the 21st and 26th and were fully justified.

Cold-wave warnings were not required for any part of the Washington district until the 27th, except for Mississippi, western Tennessee, extreme northwestern Florida, and along the Alabama coast, on the 22d. On the 27th an extensive area of low pressure was moving rapidly eastward over the region of the Great Lakes and the Eastern States and it was followed by an area of high pressure and abnormally cold weather which had moved from Alberta southeastward to the Plains States. Cold-wave warnings were issued for the Ohio Valley, including all of Ohio, Tennessee, and the East Gulf States, and they were fully verified over most of this area. By the time the cold wave had reached eastern Ohio on the morning of the 28th, the crest of the high-pressure area had advanced to the west Gulf coast and pressure had fallen

to such an extent over the Plains States and the Northwest that warnings were ordered only for extreme northern Florida and the coast regions of Georgia and South Carolina.

Frost warnings were issued for portions of the East Gulf and south Atlantic States on numerous dates and were, in the main, well verified.—*Charles L. Mitchell.*

WARNINGS FROM OTHER DISTRICTS.

Chicago Forecast District.—With the exception of stock warnings on the morning of December 11 for Montana and Wyoming, no special advices of any kind were issued from the Chicago forecast center until the third decade of December, the winter up to that time being unusually mild and open. However, on the morning of December 20, a cold, high pressure area appeared in the Canadian Northwest preceded by a low of marked energy and cold wave warnings were ordered for the southern and central Plains States and the upper and lower Missouri Valley. These warnings were extended during the 21st and 22d to the eastern limits of the district. In connection with this disturbance, the stock interests in Wyoming, South Dakota, Nebraska, and Kansas were fully advised as to impending conditions, as well as heavy snow warnings issued for southern and central Wisconsin, eastern Iowa, and extreme northern Illinois. No warnings of any kind were necessary during the balance of the month.

During the period from December 10 to 20, inclusive, special forecast service was rendered the Liberal Auto & Supply Co., Liberal, Kans., each evening forecasts being telegraphed containing the expected weather for the next two days, as well as the probable minimum temperature for the following morning. This service was desired in connection with the work of erecting a large concrete and steel building. That the forecasts were much appreciated is shown by a copy of the following letter, which was received from the concern in question under date of December 21.

We wired you to-day: "Discontinue our weather service. Thanks." We have completed our roof on the garage building and your service has been very helpful. Your forecast has been accurate, there being scarcely a degree difference. Such service as yours makes one glad to know that he lives at this time of convenience and excellent service.

—*E. H. Haines.*

New Orleans Forecast District.—There were several windy days during the month, but no severe storms occurred. Small-craft warnings were displayed for all or part of the West Gulf coast on the 3d, 13th, 15th, 20th, 25th, and 26th, and were justified. The p. m. map of the 20th showed a well-defined disturbance over the upper Rio Grande Valley and southeast storm warnings were displayed from New Orleans to Corpus Christi, and were justified.

On the 6th a disturbance was central over Texas and an area of high pressure extended from the upper Missouri Valley southwestward across the Rocky Mountain States. Cold-wave warnings were ordered for the northwestern portion of the district, but the fall in temperature, as the depression moved eastward, was not sufficient for a cold wave. This was due partly to the fact that the temperatures within the anticyclone were not very low to begin with and partly to a tendency of the anticyclone to move eastward as well as southward, so that the main body of the anticyclonic area remained north of the cyclonic area.

Cold-wave warnings for the northern and western portions of the district were issued on indications of the p. m. map of the 20th, when a depression was over New Mexico and an area of high pressure was central to the northward of eastern Montana, with conditions well defined. The warnings were verified in most localities, the temperature fall in Arkansas requiring more time than in other sections for which the warnings were issued.

On the 26th a trough of low pressure was over the Mississippi Valley and the West Gulf States and the pressure was high over western Canada. Cold-wave warnings were issued for Arkansas, eastern Oklahoma, and northern Texas, and were extended at night over northern Louisiana and to the central portion of east Texas. These warnings were generally verified. As in the preceding instance, the temperature fall in eastern and southern Arkansas, though large, was gradual. On the morning of the 28th, the cold wave reached also the lower Rio Grande Valley and the adjacent coast of Texas, with a temperature of 32° at Corpus Christi, the cold wave coming more directly south and causing a greater change on the coast than was expected.

Warnings for live-stock interests were sent out on the 6th, 21st, 26th, and 27th.

Warnings of frost or freezing temperature for coast and adjacent sections were issued on the 1st, 7th, 8th, 15th, 17th, 22d, 23d, 24th, 27th, and 28th, and were mostly verified.

Fire-weather warnings were telegraphed to Oklahoma and Arkansas on the 29th and conditions occurred as forecast.—*R. A. Dyke.*

Denver Forecast District.—On the 12th a low pressure center was over southeast Colorado. It moved northeastward and on the morning of the 13th a moderate cold wave occurred without warnings in northwest New Mexico and adjacent parts of Arizona and Colorado. This was unusual as the low pressure center was located north of the area subsequently covered by the cold wave.

On the monring of the 20th an area of low barometer of considerable intensity occupied southern Utah. During the following 24 hours the disturbance was divided by a wedge of high pressure advancing southward along the eastern slope, one center moving to eastern Kansas while the other remained in northwestern New Mexico. Live-stock warnings were issued for eastern Colorado on the morning of the 21st. A sharp fall in temperature occurred in eastern Colorado, with zero temperatures, and strong winds in some localities.—*Frederick W. Brist.*

San Francisco Forecast District.—Frost warnings were issued in northern California on December 2, 4, and 7; in southern California and the San Joaquin Valley on December 12, and throughout the interior of California on December 13 and 20. The frosts were heavy but no material damage resulted.

Storm warnings were ordered as follows: December 1, at Point Reyes and advisory at all Washington and Oregon stations; 3d, at all Washington and Oregon stations; 5th, from Tatoosh to Mendocino; 6th, from Tatoosh to San Francisco; 7th, all Washington and Oregon stations; 9th, from Tatoosh to San Francisco; 10–11th, from Tatoosh to Point Reyes; 12th, 14th, 16th, all Washington and Oregon stations; 17th, from Tatoosh to Point Reyes; 19th, from San Francisco to San Diego; 23d, from Tatoosh to San Francisco; 26th, all Washington and Oregon stations; 27th, advisory followed by southwest warnings all Washington and Oregon stations; 29th, all Washington and Oregon stations; 30th, from Tatoosh to Point Reyes; 31st, all Washington and Oregon stations.

—*G. H. Willson.*

RIVER AND FLOODS.

FLOODS DURING DECEMBER.

By H. C. FRANKENFIELD, Meteorologist.

[Weather Bureau, Washington, January 28, 1921.]

Another month passed without floods of serious character, although moderate floods were more numerous than in November, 1920. With the exceptions of those in the Connecticut, the upper Susquehanna and the Williamette Rivers, the floods occurred in the Southern rivers, and they are summarized in the following table:

Flood stages during month of December, 1920.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:	*Feet.*			*Feet.*	
White River Junction, Vt	13	15	16	14.5	15
Hartford, Conn	16	16	18	18.8	17
Hoosick:					
Hoosick Falls, N. Y	3	6	6	3.6	6
Susquehanna:					
Oneonta, N. Y	12	3	3	13.7	3
James:					
Columbia, Va	18	1	1	21.0	1
Roanoke:					
Weldon, N. C	30	(*)	4	38.4	3
Tar:					
Greenville, N. C	14	14	14	14.0	14
Neuse:					
Neuse, N. C	14	1	1	14.2	1
Do	14	9	12	16.2	9
Do	14	29	30	14.3	30
Smithfield, N. C	14	2	3	15.3	2
Do	14	9	12	17.6	11
Cape Fear:					
Elizabethtown, N. C	22	3	3	22.4	3
Do	22	10	17	30.2	12
Do	22	30	30	23.3	30
Fayetteville, N. C	35	10	11	42.0	10
Peedee:					
Cheraw, S. C	27	10	10	28.9	10
Santee:					
Rimini, S. C	12	1	(**)	14.1	19, 20
Ferguson, S. C	12	3	(**)	13.5	20
EAST GULF DRAINAGE.					
Alabama:					
Montgomery, Ala	35	24	25	35.5	24
Selma, Ala	35	25	28	38.0	26
Coosa:					
Gadsden, Ala	22	16	19	22.4	17, 18
Lock No. 4, Ala	17	15	20	18.2	16
Etowah:					
Canton, Ga	11	14	15	20.0	14
Cahaba:					
Centerville, Ala	25	14	14	26.0	14
Tombigbee:					
Demopolis, Ala	39	25	(**)	45.6	30
Pascagoula:					
Merrill, Miss	20	27	(**)	22.2	29
Leaf:					
Hattiesburg, Miss	19	24	26	22.0	25
Pearl:					
Jackson, Miss	20	23	(**)	26.6	31
Columbia, Miss	18	23	(**)	24.5	25
West Pearl:					
Pearl River, La	13	21	21	13.1	21
Do	13	28	(**)	15.9	27, 30, 31
MISSISSIPPI DRAINAGE.					
French Broad:					
Penrose, N. C	13	14	15	14.5	15
Asheville, N. C	4	14	14	4.4	14
Big Pigeon:					
Newport, Tenn	6	14	14	9.0	14
Holston, North Fork:					
Mendota, Va	8	14	14	9.0	14
Ouachita:					
Camden, Ark	30	25	(**)	33.0	28
Sulphur:					
Finley, Tex	24	27	30	24.7	29
Ringo Crossing, Tex	20	9	9	20.0	9
Do	20	22	26	23.0	25
WEST GULF DRAINAGE.					
Trinity:					
Dallas, Tex	25	23	24	29.4	23
PACIFIC DRAINAGE.					
Willamette:					
Eugene, Oreg	10	29	(**)	16.5	30
Albany, Oreg	20	31	31	21.1	31
Oregon City, Oreg	12	31	31	12.3	31
Jefferson, Oreg	10	29	(**)	13.0	30
South Fork, Oreg	12	29	29	16.1	29

* Continued from November. ** Continued into January.

Atlantic drainage, Connecticut River.—Following heavy rains on the 5th, advisory warnings were issued on the 6th for sharp rises in the lower Connecticut River, and on the 7th the stage at Hartford, Conn., was 15.2 feet, 0.8 foot below the flood stage. Much of this water was caused by release of the surplus water at Bellows Falls, Vt., and Turners Falls, Mass. The waters carried away a temporary bridge at Brattleboro, Vt., entailing a loss of $30,000. Another heavy rain occurred during the night of December 14–15, mail advices were issued to up-river points on the 14th, and general flood warnings were ordered at 9 a. m. of the 15th, with an indicated crest of 17 feet at Hartford. A stage of 18.8 feet was reached at 2:30 a. m. December 17, 2.8 feet above the flood stage. The excess above the forecast stage of 17 feet was doubtless due to the discharge of surplus water at dams above Hartford, the season having been so wet that there was no need for storage of the extra water. At White River Junction, Vt., the crest stage was 14.5 feet at 1 p. m. December 15, 1.5 feet above flood stage. No other flood stages were reported, and there were no losses worthy of mention.

There were also moderate floods in the Susquehanna River in the vicinity of Oneonta, N. Y., on December 3 and 12, flood stages having been slightly exceeded.

James River.—The James River, of Virginia, at Columbia, Va., was in flood on December 1, caused by heavy rains on November 30. It was a local flood, and the crest stage was 21 feet, 3 feet above the flood stage, but flood stages were not even approximated over other portions of the river, except at Richmond, where there was a crest stage of 9.7 feet on December 2, 0.3 foot below the flood stage; no damage was reported.

Roanoke River.—The Roanoke River flood of November continued through December 4, and the crest stage of 38.4 feet at Weldon on that day was 8.4 feet above the flood stage. The necessary warnings had been given on November 29 and December 1. Apparently little or no damage was caused by this flood.

Neuse River.—The flood stage of 14 feet was just about reached at Neuse, N. C., on December 1, and the river was above the flood stage of 14 feet on the 2d and 3d at Smithfield, N. C., 35 miles below Neuse, with a crest of 15.3 feet on December 2. Warnings were issued on December 1, but the crest stages occurred a day earlier than had been anticipated, the trouble having been due, partly at least, to the nonreceipt of early information from headwaters. Additional heavy rains on the 8th and 9th necessitated more flood warnings on the 9th for the Neuse River, a stage of 18 feet at Neuse, and Smithfield, N. C., being forecast for December 11. The crest stages on that date were 16.2 and 17.6 feet, respectively, flood stage being at 14 feet. On December 10 warnings were issued for a rise for several days in the Tar River, with a stage of 18 feet forecast for Tarboro, N. C., on December 13, and 15 feet for Greenville, N. C., on December 14. These stages were not reached, but on the morning of the 14th, the river at Greenville touched the flood stage of 14 feet.

Cape Fear River.—Warnings were issued on December 2 for a stage of 24 feet, or 2 feet above flood stage, by December 4 in the lower Cape Fear River, at Elizabethtown, N. C., and the crest stage was 22.4 feet on the 3d. On December 9 warnings were issued for a stage of 38 feet at Fayetteville, N. C., on the 10th, and for 27 feet

at Elizabethtown, N. C., on the 11th. The crest stage at Fayetteville was 42 feet, or 7 feet above flood stage, at 1 p. m. December 10, and at Elizabethtown 30.2 feet, or 8.2 feet above flood stage, on December 12.

The losses reported from these North Carolina floods amounted to only about $3,000, while the money value of the property saved by the warnings was estimated at $27,500.

The same general rain conditions that caused the North Carolina floods also extended to the southward and westward, and at Cheraw, S. C., on the Peedee River, the flood stage of 27 feet was exceeded by 1.9 feet on December 10. Although the flood stage had not been forecast, warnings had been issued to the lumber interests, and property to the amount of $3,000 was saved. Advisory warnings were also issued on the 14th and 28th. In both instances the crest stages were slightly below flood stage.

The lower Santee River was in flood at the end of November, 1920, and flood stage continued throughout the month, with a crest stage of 14.1 feet at Rimini, S. C., on the 19th–20th, and of 13.5 feet at Ferguson, S. C., on the 20th, flood stage being at 12 feet at both places. Further advices regarding the flood were issued on the 15th and 27th, the latter extended so as to include the entire watershed of the Santee River.

As there is little or no grazing in the swamp region at this time of the year, and as the Santee River had been high or in flood since the middle of November, 1920, there was no damage from the floods.

East Gulf drainage.—There were very heavy rains over the watershed of the Alabama River on the 13th and 14th, and general flood warnings were issued on the 13th. While the flood stages were generally exceeded, the crests in the Tallapoosa and Alabama Rivers were lower by several feet than had been anticipated. Operation of the gates at Lock 12, Coosa River, and somewhat uneven rainfall distribution may have contributed to cause the discrepancies. Resulting losses and damage from the floods amounted to about $15,000, and about the same amount was saved by the warnings. Warnings were issued at the same time for the Black Warrior and Tombigbee Rivers. The warning of December 14 for 46 or 47 feet in the Black Warrior River at Tuscaloosa, Ala., on December 15 or 16 was a failure, the crest stage having been but 25.2 feet (flood stage 46 feet) on December 15. As in the case of the Alabama River, uneven distribution of the precipitation was probably the cause of the failure of the forecast, as a sufficient amount to justify the forecast occurred at the reporting stations. The warnings of the 22d and 23d were not much below the forecast stage for the Black Warrior River, while for the Tombigbee River they were very accurate. Losses were very small indeed.

Floods were also general over the Pascagoula watershed of Mississippi on approximately the same dates as to the eastward, and the usual warnings were issued at the proper times for stages above the flood stage. The warnings were fully verified, as will be seen by the table and were the means of saving property valued at $45,000. The losses and damage reached an approximate total of $200,000.

The heavy rains of December 13 brought the waters of the French Broad River and tributaries to stages slightly above the flood stage. No warnings were issued and no damage was done. A similar occurrence was reported at Mendota, Va., on the north Fork of the Holston River.

The stage of 11.3 feet at Knoxville, Tenn., on the 15th was accurately forecast, but another forecast issued on the 15th for a stage slightly above 13 feet on the following day (flood stage 12 feet) failed by about 2 feet, the crest having been only 11 feet. No damage was reported.

The flood in the Ouachita River of Arkansas was accurately forecast, and a crest of 33 feet, 3 feet above the flood stage, was reached at Camden, Ark., on December 28. The flood continued into January, 1921. The damage done was nominal.

Flood stages were just about reached at places along the Sulphur Fork of Red River on three dates during the month. No warnings were issued. The Trinity River at Dallas, Tex., was also above the flood stage on December 23 and 24, but without resulting damage. No other flood stages were reported along the river, although the stage at Trinidad, Tex., on December 27 was 25.8 feet, 2.2 feet below the flood stage.

The only other flood was in the Willamette River of Oregon. It was in progress at the close of the month, at which time the stage at Portland was 14 feet, 1 foot below the flood stage. A report on this flood will be made in the MONTHLY WEATHER REVIEW for January, 1921.

NOTE.—A report on the flood in the Eel River of California on November 17, 18, and 19, 1920, was received too late for publication in the November REVIEW. This flood was caused by heavy, warm rains, and melting snows, and caused damage to the amount of about $60,000, of which perhaps $50,000 was incurred by railroad interests. Warnings were issued as soon as possible, although somewhat late at first on account of unsatisfactory communications.

Estimated losses by floods.

River and district.	Farms, buildings, machinery, live stock, etc.	Suspension of business.	Value of warning.	Tangible property, roads, bridges, etc.	Crops matured.	Crops prospective.
Raleigh, N. C.:						
Roanoke	....	$3,000	....	....	....	$27,500
Charleston, S. C.:						
Pee Dee	....	....	....	....	....	3,000
Montgomery, Ala.:						
Coosa	$200	10,700	$2,000	....	$2,500	16,750
Mobile, Ala.:						
Black Warrior	....	....	....	....	1,500	2,000
Meridian, Miss.:						
Leaf	136,300	13,500	5,050	$24,950	19,650	45,000

MEAN LAKE LEVELS DURING DECEMBER, 1920.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Jan. 5, 1921.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during December, 1920:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.25	580.12	571.89	245.40
Above or below—				
Mean stage of November, 1920	−0.23	−0.18	−0.06	+0.17
Mean stage of December, 1919	−0.08	−0.04	+0.02	−0.34
Average stage for December, last 10 years	−0.05	−0.01	+0.15	−0.06
Highest recorded December stage	−0.88	−2.46	−1.64	−2.21
Lowest recorded December stage	+1.05	+1.12	+1.03	+1.97
Average relation of the December level to—				
November level	....	−0.20	−0.10	−0.20
January level	....	+0.20	+0.10	+0.00

* Lake St. Clair's level in December, 574.77 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, DECEMBER, 1920.

By J. WARREN SMITH, Meteorologist.

Mild, open weather for the season prevailed generally during the first half of December, and no damaging temperatures were reported from any section of the country. Field work made good progress, except for delay by rain or wet soil in portions of the South. Under the influence of the mild weather and ample soil moisture, winter grains maintained their previously reported good condition; wheat was stooling well in the Great Plains section.

The last half of the month was considerably colder, however, especially the last decade in the upper Great Plains region where unseasonably low temperatures prevailed. The cold, stormy weather during much of the last decade was unfavorable for outdoor activities and very little farm work was accomplished, except in parts of the South. Considerable damage was done to general winter truck in the western Gulf region and some damage to tender truck in the Southeast. There was considerable freezing and thawing in some of the Ohio Valley localities which unfavorably affected winter wheat, but in general no extensive damage to fall-sown grains was reported.

Ranges and pastures continued in good condition during most of the month, except that the weather was unfavorable the latter part in the Great Plains and Rocky Mountain sections, with considerable stock shrinkage in some localities, due to cold weather and closed ranges. Feeding was necessary during much of this period in all the northern part of the country except on the upper Pacific coast.

Citrus fruits were favorably affected by the weather in California and made satisfactory development; by the middle of the month shipment of navel oranges had begun from the great valley of that State. The satsuma orange crop was satisfactory in Alabama where no material damage from the weather was experienced; by the close of the month harvest was nearly completed. Citrus fruits continued in satisfactory condition in Florida, and shipments of strawberries were being made from that State the latter part of the month.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1920.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	45.3	−1.0	Thomasville	76	12	Valley Head	15	24	7.85	+2.92	Marion	12.22	Tuscumbia	3.57
Arizona	41.3	−1.8	Tucson	80	1	3 stations	− 4	23†	0.22	−1.00	Blue	1.98	25 stations	0.00
Arkansas	43.2	+1.2	Texarkana	74	31	Dutton	6	28	5.95	+1.92	Malvern	9.19	Fort Smith	2.14
California	45.7	−1.0	El Cajon	82	14	Madeline	−11	12	5.66	+1.63	Wrights	23.47	5 stations	0.00
Colorado	24.4	−2.8	2 stations	71	1	Crested Butte	−38	15	0.89	−0.24	Savage Basin	5.38	2 stations	T.
Florida	58.6	−0.8	Bartow	90	13†	Garniers	21	29	3.35	+0.63	Monticello	9.56	Moore Haven	0.63
Georgia	47.0	+0.2	St. George	80	13	2 stations	14	25	5.57	+1.31	2 stations	9.38	Augusta	2.64
Hawaii (November)	71.0	−0.7	Mahukona	93	17	2 stations	47	16†	5.86	−1.80	Waiakamoi	21.96	Lahaina	0.04
Idaho	27.9	+2.3	Kooskia	62	30	Stanley	−34	15	2.69	+0.83	Pyle Creek	6.63	Lifton	0.47
Illinois	33.0	+2.8	2 stations	68	12	Kankakee	−13	28	2.81	+0.65	New Burnside	5.92	2 stations	0.83
Indiana	33.6	+1.3	3 stations	65	1†	Collegeville	−14	28	3.24	+0.53	Salamonia	5.05	Dam 39	1.51
Iowa	26.4	+2.5	Burlington	65	3	Inwood	−26	24	1.16	−0.06	2 stations	2.64	Earlham	0.44
Kansas	34.5	+3.2	Johnson	74	2	Oberlin	−19	24	0.97	−0.07	Norwich	2.11	Johnson	0.10
Kentucky	38.6	+1.5	Hopkinsville	68	13	Shelbyville	4	28	2.89	−1.05	2 stations	7.02	Shelbyville	1.16
Louisiana	51.0	+0.4	Houma	79	31	3 stations	19	28	9.02	+4.10	Clinton	14.63	Robeline	3.77
Maryland-Delaware	37.7	+3.2	College Park, Md	71	14	Oakland, Md	− 5	21	3.42	+0.07	Fallston, Md	4.62	Western Port, Md	1.95
Michigan	29.3	+4.3	3 stations	60	5†	Humboldt	−30	25	3.31	+1.25	Whitefish Point	5.44	Humboldt	1.35
Minnesota	19.3	+4.3	2 stations	50	11†	2 stations	−29	24†	0.78	+0.02	Crookston	2.24	Beardsley	T.
Mississippi	47.0	−0.1	3 stations	76	12†	5 stations	18	27†	8.41	+3.11	Monticello	15.58	Biloxi	4.50
Missouri	35.6	+2.6	Dean	77	15	3 stations	−10	28	1.93	−0.22	Parma	6.76	Fayette	0.40
Montana	25.5	+2.5	Chinook	65	15	Chinook	−35	23	0.68	−0.17	Heron	5.52	Townsend	0.09
Nebraska	27.0	+1.2	Imperial	73	1	2 stations	−28	24	0.78	+0.04	Ainsworth	1.80	Alma	0.18
Nevada	32.4	+0.4	Las Vegas	66	31	Clover Valley	−12	14	1.00	−0.08	Gold Creek	1.05	2 stations	T.
New England	28.4	+2.9	Chestnut Hill, Mass.	67	6	Pittsburg, N. H.	−26	26	5.48	+2.19	Rumford, Me	9.06	Houlton, Me	2.16
New Jersey	36.4	+3.4	Clayton	69	14	Culvers Lake	− 1	29	5.10	+1.34	Little Falls	6.63	Camp Dix	2.86
New Mexico	33.0	−0.8	2 stations	75	29†	Dulce	−26	27	0.28	−0.44	Chama	3.40	22 stations	0.00
New York	29.9	+3.7	Medford	67	5	Gabriels	−21	26	4.23	+1.22	Adams Center	8.32	Dansville	0.91
North Carolina	42.5	+1.3	Newbern	75	14	2 stations	11	25	5.83	+1.93	Highlands	13.01	Pinehurst	3.58
North Dakota	15.2	+2.2	New Salem	59	1	Langdon	−32	27	0.32	−0.22	Hannah	1.50	Donnybrook	T.
Ohio	33.8	+2.9	Portsmouth	68	13	Paulding	− 8	28	2.14	−0.57	Montpelier	4.75	Frankfort	0.93
Oklahoma	41.2	+2.0	Hugo	80	12	2 stations	3	23†	1.90	+0.47	Perry	4.02	Lawtonka Lake	0.09
Oregon	36.6	+2.0	Florence	67	30	Lapine	−23	14	6.20	+1.90	Deadwood	23.59	Blitzen	0.81
Pennsylvania	33.4	+2.9	Irwin	68	13	Ebensburg	− 7	21	3.28	+0.13	Gordon	6.77	Claysville	1.53
Porto Rico														
South Carolina	46.1	−0.2	2 stations	75	4†	Walhalla	18	25	4.01	+0.60	Liberty	7.97	Columbia	2.26
South Dakota	22.7	+1.4	Spearfish	73	2	Pollock	−33	24	0.54	+0.02	Canton	1.85	3 stations	T.
Tennessee	41.5	+1.5	Moscow	69	4	Rugby	6	29	5.01	+0.31	Copperhill	9.51	Greeneville	1.76
Texas	50.0	+0.5	Harlingen	92	21	Romero	5	24	1.50	−0.66	Port Arthur	8.26	21 stations	0.00
Utah	26.7	−0.2	Spanish Fork	68	2	East Portal	−34	15	1.20	+0.23	Silver Lake	5.26	Jozella Ranch	0.06
Virginia	39.4	+1.9	Franklin	73	14	Burkes Garden	9	9†	3.25	−0.11	Newport News	6.03	Quantico	1.50
Washington	36.1	+2.7	Anacortes	67	3	3 stations	− 2	13†	6.29	+1.01	Forks	23.73	Irene Mountain	1.01
West Virginia	35.6	+2.5	2 stations	70	4†	3 stations	0	19†	2.56	−0.87	Davis	5.13	Kanawha Falls	1.32
Wisconsin	24.5	+3.6	Racine	59	3	2 stations	−32	25	1.95	+0.64	Waukesha	3.75	Spooner	0.45
Wyoming	22.6	+1.4	Echeta	70	3	Afton	−35	14	0.62	−0.08	Alta	2.53	Hyattville	0.00

*For description of tables and charts, see this REVIEW, January, 1920, p. 54.
†Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, December, 1920.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England.							31.7	+2.6										77	5.05	+1.6										7.0		
Eastport	76	67	85	29.79	29.88	-.10	27.5	+2.2	52	2	33	-7	26	22	27	35	21	76	3.31	-0.7	13	10,946	nw.	51	se.	15	3	12	16	7.1	14.2	5.5
Greenville, Me.	1,070	6		28.70	29.91		20.2		39	15	26	-15	26	14	24				6.93		16						5	7	19		30.3	20.0
Portland, Me.	103	82	117	29.81	29.94	-.09	29.8	+2.7	51	5	36	2	26	24	21	26	21	71	6.05	+2.4	11	6,987	w.	50	se.	14	9	7	15	6.1	12.3	7.2
Concord	288	70	79	29.60	29.93	-.13	29.2	+2.8	52	14	36	0	26	23	25				5.80	+2.4	6	4,046	nw.	33	nw.	2	6	6	19	7.3	8.0	6.9
Burlington	404	11	48	29.48	29.94	-.11	25.2	+2.7	47	14	31	-5	26	19	20				5.29	+3.6	17	7,824	s.	60	se.	14	1	6	24	8.7	24.3	6.5
Northfield	876	12	60	28.97	29.90	-.15	23.2	+2.7	45	14	31	-13	26	16	27	22	20	86	4.35	+1.6	15	4,822	s.	30	sw.	23	1	3	27	9.1	16.6	16.0
Boston	125	115	188	29.79	29.92	-.13	35.6	+4.0	58	5	42	5	26	30	22	32	28	75	3.89	-0.5	11	8,273	w.	45	se.	14	8	11	12	6.1	5.5	1.1
Nantucket	12	14	90	29.90	29.91	-.14	37.8	+1.1	57	4	43	15	26	33	21	35	32	79	4.24	+0.6	10	12,687	w.	49	ne.	9	6	7	18	7.1	2.2	0.0
Block Island	26	11	46	29.90	29.93	-.13	37.9	+1.3	57	1	42	12	26	33	19	35	32	80	6.32	+2.5	9	17,828	nw.	62	nw.	2	6	10	15	6.7	0.1	0.0
Providence	160	215	251	29.76	29.94	-.12	34.1	+2.5	55	5	40	8	26	28	20	31	28	78	3.91	0.0	10	10,672	nw.	64	se.	14	7	12	12	5.8	3.0	1.2
Hartford	159	122	140	29.77	29.95	-.12	33.6	+3.8	60	14	40	8	26	28	21	30	25	72	6.35	+2.8	9	5,748	nw.	38	nw.	2	4	9	18	7.1	2.6	2.7
New Haven	106	74	153	29.84	29.96	-.11	34.9	+3.1	56	14	41	10	26	29	19	31	26	74	6.06	+2.4	10	7,565	w.	43	s.	14	10	10	11	5.7	1.6	0.7
Middle Atlantic States.							38.1	+2.9										74	3.72	+0.6										6.6		
Albany	97	102	115	29.85	29.96	-.12	31.9	+4.4	60	14	38	5	26	26	19	29	25	79	4.12	+1.6	10	5,100	nw.	28	sw.	14	4	11	16	7.0	5.9	3.0
Binghamton	871	10	84	28.98	29.94	-.15	32.4	+4.7	58	14	38	12	26	27	19				2.72	+0.3	11	5,335	sw.	35	sw.	23	1	6	24	8.4	2.5	0.5
New York	314	414	454	29.62	29.97	-.12	37.8	+3.4	59	14	44	18	26	32	16	33	27	69	5.09	+1.6	11	15,518	nw.	75	nw.	2	6	12	13	6.6	1.5	T.
Harrisburg	374	94	104	29.60	30.02	-.10	36.2	+3.4	60	14	42	19	29	31	18	32	27	71	3.94	+1.3	10	4,211	w.	27	w.	5	8	5	18	6.9	2.0	T.
Philadelphia	117	123	190	29.87	30.00	-.11	39.8	+4.1	67	14	46	20	26	33	25	37	34	81	4.66	+1.6	8	8,158	nw.	38	s.	14	7	7	17	6.6	0.8	0.
Reading	325	81	98	29.64	30.00		36.9		66	14	43	18	29	31	24	33	28	71	4.75	+1.4	10	6,210	nw.	33	nw.	2	6	6	19	7.0	1.3	0.0
Scranton	805	111	119	29.09	29.97	-.13	33.6	+3.8	63	14	39	13	29	28	24	31	28	81	3.03	+0.4	13	6,300	sw.	35	sw.	23	4	8	19	7.7	2.0	0.1
Atlantic City	52	37	48	29.94	30.00	-.10	39.6	+3.2	58	14	46	19	29	33	22	36	33	79	4.27	+0.5	8	6,609	w.	30	s.	14	10	4	17	6.1	0.1	0.0
Cape May	18	13	49	30.02	30.04	-.07	40.0	+2.0	56	1	46	21	26	35	22	37	33	76	4.07	+0.3	8	8,247	nw.	40	se.	14	9	4	18	6.4	T.	0.0
Sandy Hook	22	10	55	29.95	29.97		37.8		57	14	43	20	26	33	15	35	32	80	5.16		9	14,495	sw.	54	se.	14	6	12	13	6.4	0.5	0.0
Trenton	190	159	183	29.77	29.98		37.4		66	14	44	17	29	31	23	33	29	74	4.25	+1.1	10	9,103	w.	46	w.	5	8	9	14	6.3	1.0	0.0
Baltimore	123	100	113	29.88	30.01	-.12	39.8	+2.9	68	14	46	22	29	34	23	35	29	67	3.58	+0.5	8	4,963	sw.	30	s.	22	6	7	18	6.9	0.5	0.0
Washington	112	62	85	29.89	30.02	-.11	39.3	+3.2	68	14	45	22	29	33	23	34	28	68	3.15	0.0	7	5,745	nw.	34	nw.	2	3	9	19	7.5	0.2	0.0
Lynchburg	681	153	188	29.27	30.03	-.11	40.2	+1.9	67	14	48	19	26	32	28	35	30	70	2.34	-0.9	9	5,995	w.	40	w.	14	11	10	10	5.4	0.0	0.0
Norfolk	91	170	205	29.93	30.03	-.10	45.6	+2.6	71	14	53	30	18	39	23	40	35	71	4.91	+1.4	9	10,072	w.	49	ne.	8	13	5	13	4.9	0.0	0.0
Richmond	144	11	52	29.87	30.04	-.10	41.0	0.0	67	14	49	21	26	33	27	36	33	80	1.87	-1.1	8	6,178	sw.	40	sw.	15	13	4	14	5.6	0.0	0.0
Wytheville	2,304	49	56	27.60	30.06	-.09	36.2	+0.9	63	14	43	19	25	29	27	31	26	74	2.77	-1.0	13	6,646	w.	37	w.	14	11	5	15	6.0	1.9	0.0
South Atlantic States.							47.7	+0.6										75	4.07	+0.6										5.6		
Asheville	2,255	70	84	27.67	30.10	-.06	38.8	+1.0	62	3	46	20	29	31	32	33	28	71	4.97	+0.9	10	7,474	nw.	38	e.	8	12	5	14	5.7	2.0	0.0
Charlotte	779	55	62	29.20	30.06	-.10	43.0	+0.1	64	13	51	26	25	35	30	38	33	74	4.47	+0.6	10	4,392	sw.	25	w.	17	11	5	15	5.7	0.0	0.0
Hatteras	11	12	50	30.02	30.03	-.10	50.4	+1.6	69	22	56	36	25	44	24	47	43	80	6.40	+1.3	12	11,753	w.	53	nw.	9	11	5	15	5.7	0.0	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.64	30.06	-.09	43.4	+0.7	67	14	52	25	26	35	25	39	35	77	4.35	+1.2	11	6,475	w.	35	w.	14	10	7	14	5.8	0.0	0.
Wilmington	78	81	91	29.98	30.07	-.08	48.8	+1.6	70	4	57	30	25	40	27	43	38	72	4.08	+1.0	10	5,592	w.	38	s.	22	10	7	14	5.5	0.0	0.
Charleston	48	11	92	30.02	30.08	-.07	51.4	+0.1	70	22	59	34	29	44	24	46	42	77	3.00	-0.2	16	7,211	w.	34	sw.	4	10	7	14	5.7	0.0	0.0
Columbia, S. C.	351	41	57	29.70	30.09	-.07	46.4	-0.8	69	13	55	28	29	38	29	40	35	72	2.26	-0.6	9	5,281	w.	30	w.	15	11	5	15	5.5	0.0	0.0
Greenville, S. C.	1,039	113	122	28.94	30.05		42.7		63	31	50	26	25	35	29	38	33	74	5.39		11	6,964	w.	42	w.	15	13	5	13	5.5	0.0	0.0
Augusta	180	62	77	29.88	30.08	-.08	47.6	+0.6	73	13	57	27	29	38	34	42	38	77	2.64	-0.8	9	4,229	nw.	30	nw.	27	11	4	16	5.9	0.0	0.0
Savannah	65	150	194	30.02	30.09	-.06	52.0	+0.7	71	13	61	32	25	43	28	46	42	78	5.20	+2.1	15	8,953	w.	49	w.	16	9	6	16	6.1	0.0	0.0
Jacksonville	43	209	245	30.05	30.10	-.04	55.4	+0.2	76	13	64	35	25	47	28	49	45	76	3.35	+0.4	12	8,935	nw.	48	s.	22	16	5	10	4.2	0.0	0.0
Florida Peninsula.							66.3	-0.2										80	1.37	-0.7										5.2		
Key West	22	10	64	30.03	30.05	-.03	70.6	+0.5	83	7	75	58	18	66	15	66	63	82	0.92	-0.9	7	7,429	ne.	38	nw.	28	13	10	8	4.6	0.0	0.0
Miami	25	71	79	30.05	30.08		68.0	0.0	81	23	74	43	17	62	23	63	61	81	1.72	-0.5	7	5,962	nw.	28	w.	16	8	12	11	6.0	0.0	0.0
Sand Key	23	39	72	30.00	30.03	-.05	70.8		79	23	74	60	2	68	11	67	64	81	1.25		5	11,310	ne.	50	nw.	28	10	15	6	5.0	0.0	0.0
Tampa	35	79	92	30.06	30.10	-.02	60.2	-1.0	80	13	70	39	29	51	26	54	50	76	1.46	-0.6	8	4,768	nw.	26	nw.	16	12	8	11	5.3	0.0	0.0
East Gulf States.							48.2	+0.9										76	7.24	+2.7										5.8		
Atlanta	1,174	190	216	28.82	30.08	-.08	43.1	-1.5	65	13	50	21	25	36	23	39	34	74	4.36	-0.2	10	8,912	nw.	38	nw.	26	8	8	15	6.3	0.0	0.0
Leesburg	279	10	55																													
Macon	370	78	87	29.69	30.09	-.07	47.7	+0.9	71	13	57	26	25	38	35	41	35	71	3.58	-0.8	9	4,568	nw.	38	nw.	27	10	8	13	5.6	0.0	0.0
Thomasville	273	49	58	29.80	30.10	-.05	51.4	-1.1	75	13	61	29	29	42	30	45	40	75	8.60	+4.9	9	3,397	nw.	23	n.	27	13	5	13	5.3	0.0	0.0
Pensacola	56	149	185	30.04	30.10	-.05	51.7	-2.2	71	22	59	33	28	44	23	47	44	77	5.58	+1.4	10	10,680	n.	56	sw.	22	10	7	14	5.8	0.0	0.0
Anniston	741	9	57	29.29	30.11	-.05	43.2	-1.0	65	13	52	18	25	35	31				8.75	+4.2	9	4,880	nw.	28	w.	14	10	8	13	5.8	0.0	0.0
Birmingham	700	11	48	29.33	30.11	-.05	45.6	-1.7	68	13	53	24	29	38	27	40	34	72	9.57	+5.0	10	5,623	nw.	36	se.	21	12	5	14	5.9	0.0	0.0
Mobile	57	125	161	30.03	30.09	-.06	51.0	-0.5	69	13	60	30	29	42	27	46	42	78	6.18	+1.6	11	7,849	nw.	36	nw.	4	8	9	14	5.5	0.0	0.0
Montgomery	223	100	112	29.86	30.12	-.04	47.8	-1.3	71	13	56	27	29	40	33	42	37	72	7.72	+3.2	10	4,935	w.	29	sw.	13	15	1	15	5.3	0.0	0.0
Corinth	469	6																														
Meridian	375	85	93	29.68	30.09	-.07	46.4	-0.5	71	13	55	24	29	38	32	42	37	76	9.42	+4.2	11	4,651	se.	27	se.	13	13	3	15	5.6	0.0	0.0
Vicksburg	247	65	73	29.81	30.10	-.05	48.6	-0.8	72	31	56	26	28	41	30	43	39	77	7.14	+2.1	12	6,157	se.	34	e.	6	12	3	16	5.8	0.0	0.0
New Orleans	53	76	84	30.04	30.10	-.03	54.1	-0.3	77	13	62	34	28	46	28	50	47	83	8.70	+4.2	10	4,630	se.	23	nw.	4	9	6	16	6.4	0.0	0.0
West Gulf States.							50.1	+1.1										73	3.07	+0.2										4.9		
Shreveport	249	77	93	29.80	30.08	-.05	48.6	-0.3	74	31	57	24	28	40	27	43	38	73	6.37	+2.0	14	6,403	se.	37	w.	13	13	7	11	5.2	0.0	0.0
Bentonville	1,303	11	44	28.60	30.00	-.13	39.2	+1.7	68	31	48	10	24	30	30				2.67	-0.1	10	5,639	s.	26	se.	20	11	7	13	5.5	2.1	0.0
Fort Smith	457	79	94	29.53	30.02	-.11	43.0	+1.3	73	31	52	18	28	34	32	37	31	68	2.14	-0.7	7	7,124	e.	50	sw.	16	16	3	12	4.8	T.	0.0
Little Rock	357	136	144	29.66	30.05	-.09	44.6	+1.1	67	13	52	19	28	37	29	40	35	73	6.99	+2.8	12	7,638	s.	42	w.	13	11	7	13	5.6	T.	0.0
Brownsville	57	4	26																													
Corpus Christi	20	69	77	30.03	30.05	-.07	59.9	+3.3	82	12	68	32	28	52	29	54	49	74	0.24	-1.1	3	8,422	se.	39	n.	15	8	12	11	5.8	0.0	0.0
Dallas	512	109	117	29.49	30.05		48.2		77	12	58	22	28	38	32				1.01		7	7,579	se.	37	sw.	21	16	7	8	4.2	0.0	0.0
Fort Worth	670	106	114	29.30	30.03	-.09	48.3	+0.8	77	12	59	20	28	38	34	42	37	70	1.31	+0.1	5	8,282	nw.	35	nw.	13	17	7	7	3.8	0.0	0.0
Galveston	54	106	114	30.02	30.08	-.04	56.0	-0.3	70	12	61	34	28	50	19	52	49	80	6.49	+2.8	7	8,597	se.	35	nw.	13	10	6	15	5.7	0.0	0.0
Groesbeck	461	11	56	29.54	30.03		49.9		79	12	61	22	28	39	36	43	39	74	1.90		7	8,416	s.	40	s.	21	16	6	9	4.1	0.0	0.0
Houston	138	111	121	29.91	30.06		55.6	+1.1	79	12	65	28	28	46	30				3.98		10	6,825	se.	31	s.	21	11	9	11	5.0	0.0	0.0
Palestine	510	64	72	29.52	30.06	-.06	50.6	+1.2	78	12	60	22	28	41	30	43	37	69	3.45	-0.2	8	6,738	s.	33	s.	21	13	8	10	5.0	0.0	0.0
Port Arthur	34	58	66	30.02	30.06		53.4		71	12	60	29	28	46	25	49	46	83	8.26		12	7,846	s.	34	nw.	13	9	6	16	6.2	0.0	0.0
San Antonio	701	119	132	29.31	30.04	-.07	54.7	+1.6	83	12	66	27	28	44	33	47	40	62	0.16	-1.4	5	6,140	nw.	41	nw.	13	16	9	6	3.6	0.0	0.0
Taylor	582	55	63	29.46	30.08	-.03	51.0	+0.4	80	12	63	22	28	39	40				0.88	-1.7	10	6,697	s.	33	nw.	13	14	7	10	4.5	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, December, 1920*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F		°F	°F	°F	°F	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee.							37.6	+ 0.9										76	3.19	− 0.2										7.1		
Chattanooga	762	189	213	29.27	30.10	− .06	42.8	+ 0.2	62	13	50	21	25	36	26	38	32	71	8.02	+ 3.7	9	6,259	sw.	36	w.	17	11	2	18	6.4	0.0	0.0
Knoxville	996	102	111	29.00	30.08	− .08	41.0	+ 1.3	60	13	48	23	25	34	25	36	31	73	5.03	+ 0.9	10	5,158	ne.	32	sw.	14	12	3	16	6.2	0.0	0.0
Memphis	399	76	97	29.65	30.08	− .07	44.6	+ 1.1	65	12	51	20	28	38	24	40	36	75	7.11	+ 2.7	11	7,776	s.	40	sw.	13	12	5	14	5.7	0.0	0.0
Nashville	546	168	191	29.47	30.07	− .08	41.6	+ 0.5	61	13	49	15	28	34	30	37	32	73	2.99	− 0.8	8	8,248	w.	42	sw.	13	13	3	15	5.8	T.	0.0
Lexington	989	193	230	28.96	30.06	− .08	36.2	− 0.2	58	13	42	9	28	30	22	.....	.....	.....	1.40	− 1.9	11	12,942	sw.	54	sw.	14	6	3	22	7.5	2.5	0.0
Louisville	525	219	255	29.45	30.05	− .09	38.1	0.0	59	12	44	8	28	32	24	34	30	74	2.09	− 1.6	8	11,223	w.	57	sw.	14	7	6	18	6.8	3.0	0.0
Evansville	431	139	175	29.56	30.04	− .09	38.4	+ 2.0	65	12	45	8	28	32	24	35	30	75	3.86	0.0	7	10,615	sw.	54	w.	14	7	9	15	6.3	2.0	0.0
Indianapolis	822	194	230	29.08	29.99	− .13	33.2	+ 0.6	56	3	40	− 3	28	27	31	31	27	80	3.27	+ 0.2	11	11,431	w.	52	w.	15	2	8	21	7.8	5.6	T.
Royal Center	736	11	55	29.14	29.97	.....	30.1	.....	57	13	37	−12	28	23	36	28	25	81	3.29	.....	12	9,799	w.	47	sw.	14	7	9	15	6.6	8.7	2.7
Terre Haute	575	96	129	29.35	29.98	.....	34.0	.....	61	12	41	− 3	28	27	30	31	28	79	3.69	.....	11	9,109	s.	48	sw.	13	4	9	18	7.2	5.7	0.0
Cincinnati	628	11	51	29.33	30.03	− .10	35.4	+ 1.0	60	13	42	4	28	29	25	.....	30	81	1.38	− 1.6	10	8,157	sw.	45	sw.	14	8	3	20	7.3	0.9	0.0
Columbus	824	179	222	29.11	30.01	− .11	34.0	+ 1.2	61	13	40	2	28	28	24	31	27	77	1.60	− 1.2	14	10,138	w.	62	w.	15	3	4	24	8.3	3.3	0.0
Dayton	899	181	216	28.98	29.97	.....	34.0	+ 0.9	60	13	40	0	28	28	26	31	28	79	1.54	− 1.1	10	10,401	w.	52	w.	15	3	9	19	7.6	2.5	T.
Elkins	1,947	59	67	27.92	30.05	− .07	33.6	+ 1.1	61	4	42	7	19	25	36	30	26	78	2.78	− 0.6	17	5,367	w.	33	sw.	14	2	8	21	8.2	8.2	0.0
Parkersburg	638	77	84	29.36	30.04	− .10	37.8	+ 2.6	62	4	44	18	28	31	26	33	28	74	1.68	− 1.1	17	5,245	sw.	35	w.	15	3	8	20	8.0	1.8	0.0
Pittsburgh	842	353	410	29.07	30.00	− .14	35.6	+ 0.9	61	4	42	15	28	30	24	32	27	73	1.94	− 0.8	12	10,434	w.	49	w.	15	4	5	22	7.9	1.2	0.0
Lower Lake Region.							31.6	+ 2.5										79	3.08	+ 0.2										8.4		
Buffalo	767	247	280	29.06	29.91	−0.15	32.7	+ 2.6	58	4	38	14	25	28	21	30	27	81	3.36	0.0	17	15,761	w.	96	sw.	23	2	5	24	8.7	14.4	0.8
Canton	448	10	61	29.41	29.91	.....	23.3	+ 0.6	48	14	29	− 4	9	18	21	.....	.....	.....	5.41	+ 1.8	20	7,695	w.	58	sw.	23	3	3	25	8.3	24.3	8.6
Oswego	335	76	91	29.54	29.93	− .13	30.6	+ 1.4	52	4	36	− 1	26	25	21	29	26	85	4.50	+ 0.9	16	9,522	se.	43	sw.	23	1	2	28	8.8	30.2	6.5
Rochester	523	86	102	29.35	29.94	− .12	31.8	+ 2.9	58	14	37	5	26	26	22	29	25	75	2.95	+ 0.1	18	7,651	sw.	50	sw.	23	1	5	25	8.6	18.0	3.0
Syracuse	597	97	113	29.28	29.94	− .13	30.6	+ 2.3	59	14	36	− 1	26	25	24	.....	.....	.....	3.38	+ 0.7	17	9,349	sw.	42	se.	14	1	5	25	8.3	14.0	2.0
Erie	714	130	166	29.14	29.93	− .14	33.7	+ 2.0	58	14	39	12	28	28	22	31	27	78	2.12	− 0.9	17	14,595	sw.	54	sw.	23	2	3	26	8.6	7.3	0.0
Cleveland	762	190	201	29.11	29.95	− .14	33.6	+ 2.5	60	13	39	9	28	28	23	31	27	79	1.64	− 0.9	14	12,374	w.	48	w.	5	1	6	24	8.5	5.3	0.0
Sandusky	629	62	103	29.25	29.95	− .14	34.0	+ 2.9	62	13	39	6	28	29	22	.....	.....	.....	1.77	− 0.6	15	11,824	sw.	54	sw.	14	1	8	22	8.1	3.2	0.0
Toledo	628	208	243	29.25	29.95	− .13	33.2	+ 2.7	60	13	38	4	28	28	23	31	27	77	2.86	+ 0.6	13	12,753	sw.	75	sw.	14	3	8	20	7.9	6.0	0.6
Fort Wayne	856	113	124	29.01	29.96	.....	31.6	+ 4.3	57	13	37	− 8	28	26	29	30	26	78	3.35	.....	11	9,043	w.	48	sw.	14	2	9	20	8.1	4.7	T.
Detroit	730	218	245	29.12	29.93	− .14	32.8	+ 3.3	57	13	38	4	28	28	20	30	27	82	2.84	+ 0.4	12	11,032	w.	61	sw.	14	0	7	24	8.5	7.3	0.5
Upper Lake Region.							28.3	+ 3.8										84	3.25	+ 1.2										8.3		
Alpena	609	13	92	29.19	29.87	− .15	29.6	+ 4.8	52	3	34	11	29	25	19	28	27	89	3.77	+ 1.6	14	9,566	w.	44	se.	13	2	7	22	8.1	16.6	6.5
Escanaba	612	54	60	29.18	29.87	− .16	27.2	+ 5.6	49	13	33	− 7	25	22	29	26	23	85	2.70	+ 1.0	12	7,277	nw.	36	n.	22	3	8	20	7.8	13.7	8.0
Grand Haven	632	54	89	29.20	29.89	− .16	31.8	+ 1.7	59	13	37	12	28	27	19	31	28	85	4.17	+ 1.7	22	10,940	w.	53	sw.	14	2	3	26	8.9	11.5	1.0
Grand Rapids	707	70	87	29.12	29.91	− .14	32.0	+ 3.2	57	13	37	9	28	27	22	30	28	83	4.19	+ 1.6	19	5,475	w.	30	w.	14	1	5	25	9.0	13.6	0.5
Houghton	684	62	99	29.11	29.86	− .16	25.0	+ 4.1	47	12	30	− 7	25	20	22	.....	.....	.....	4.58	+ 2.1	22	7,816	w.	46	w.	14	2	3	26	8.8	39.9	16.0
Lansing	878	11	62	28.94	29.90	.....	30.6	+ 3.8	56	13	36	3	28	25	25	29	27	88	3.94	+ 1.9	21	5,889	w.	32	sw.	14	0	5	26	9.0	9.9	0.8
Ludington	637	60	66	29.17	29.88	.....	31.4	.....	57	13	36	14	24	27	19	30	27	85	4.01	.....	19	9,392	se.	53	w.	14	1	5	25	8.8	15.0	2.7
Marquette	734	77	111	29.06	29.88	− .14	27.0	+ 4.0	51	13	32	1	25	22	22	.....	.....	.....	2.27	− 0.2	15	8,079	w.	38	sw.	24	0	5	26	.....	14.9	8.6
Port Huron	638	70	120	29.19	29.90	− .16	32.2	+ 4.9	55	13	37	3	28	27	23	30	28	85	2.51	+ 0.3	15	10,091	w.	48	sw.	14	1	8	22	8.4	9.4	1.8
Saginaw	641	69	77	29.19	29.90	.....	31.4	.....	56	3	37	7	28	28	24	30	27	85	3.71	+ 1.8	18	7,425	se.	39	sw.	14	1	7	23	8.6	7.0	2.0
Sault Ste. Marie	614	11	52	29.16	29.87	− .13	25.2	+ 4.7	45	14	30	− 1	25	20	22	24	22	84	4.44	+ 2.1	20	7,101	se.	28	nw.	6	2	5	24	8.5	33.1	14.6
Chicago	823	140	310	29.03	29.94	− .14	32.4	+ 3.1	62	3	38	− 4	28	27	23	30	26	77	3.33	+ 1.3	13	10,597	w.	48	w.	14	6	9	16	6.9	4.4	0.4
Green Bay	617	109	144	29.20	29.88	− .16	26.5	+ 4.2	52	13	32	− 8	25	21	31	24	21	79	1.70	− 0.1	10	8,504	w.	54	w.	14	4	7	20	8.0	12.4	3.1
Milwaukee	681	125	139	29.14	29.90	− .16	29.8	+ 3.8	57	3	35	− 5	28	24	26	28	24	77	3.12	+ 1.2	12	8,221	w.	45	e.	21	3	8	20	7.9	8.7	2.0
Duluth	1,333	11	47	28.64	29.90	− .15	19.3	+ 1.6	41	13	25	−12	24	14	23	18	17	92	1.07	− 0.2	8	9,933	nw.	50	nw.	14	5	5	21	7.8	6.5	5.0
North Dakota.							16.0	+ 4.2										85	0.34	− 0.2										6.0		
Moorhead	940	50	58	28.91	29.97	− .11	17.4	+ 6.7	38	12	24	−18	27	10	43	16	14	84	0.65	− 0.1	7	7,117	nw.	35	nw.	14	7	9	15	6.5	5.1	0.2
Bismarck	1,674	8	57	28.14	30.00	− .08	17.8	+ 2.8	47	3	28	−20	27	8	43	16	13	84	0.29	− 0.3	4	6,316	nw.	40	nw.	14	11	7	13	5.5	3.2	1.5
Devils Lake	1,482	11	44	28.30	29.95	− .11	11.6	+ 3.6	36	28	19	−24	27	4	41	11	9	92	0.30	− 0.1	7	6,428	nw.	36	nw.	15	11	5	15	5.8	3.2	2.2
Ellendale	1,457	10	56	28.34	29.96	.....	18.4	.....	47	11	27	−22	24	10	49	16	14	86	0.20	.....	4	10,796	nw.	54	nw.	15	6	11	14	6.4	1.7	0.3
Grand Forks	835	12	89	.....	.....	.....	14.0	.....	34	3	22	−24	27	7	45	14	.....	.....	0.49	.....	4	.....	nw.	35	nw.	15	13	3	15	.....	2.7	0.7
Williston	1,878	41	48	27.88	29.94	− .12	17.4	+ 3.8	49	2	27	−19	27	8	35	15	11	77	0.13	− 0.5	4	5,270	w.	36	nw.	16	10	7	14	5.9	1.3	T.
Upper Mississippi Valley.							30.1	+ 2.8										81	1.71	− 0.1										7.0		
Minneapolis	918	102	208	28.88	29.90	.....	23.6	.....	46	11	29	−11	27	18	35	.....	.....	.....	0.62	− 0.3	6	8,853	nw.	43	nw.	15	5	10	16	7.2	9.4	3.6
St. Paul	837	236	261	28.99	29.93	− .15	23.0	+ 3.7	44	11	28	−12	28	18	34	.....	.....	.....	0.88	− 0.2	6	10,150	nw.	51	w.	15	4	6	21	7.5	10.8	4.2
La Crosse	714	11	48	29.12	29.92	− .16	25.3	+ 2.5	51	13	31	−10	28	19	27	.....	.....	.....	1.86	+ 0.5	9	4,173	w.	22	w.	15	3	6	22	8.2	16.2	4.0
Madison	974	70	78	28.85	29.94	− .14	26.2	+ 3.5	54	13	32	−10	28	21	24	25	23	90	1.33	− 0.4	13	7,565	w.	33	w.	14	2	8	21	8.0	8.0	1.0
Wausau	1,247	4	.....	28.51	29.89	.....	22.4	.....	48	13	28	−19	25	17	31	.....	.....	.....	1.62	.....	10	.....	nw.	.....	.....	.....	3	7	21	8.0	15.1	8.3
Charles City	1,015	10	49	28.83	29.94	− .16	23.7	+ 4.7	48	11	30	−14	24	17	27	22	21	90	1.83	+ 0.6	5	5,689	nw.	30	nw.	15	5	7	19	7.5	16.1	4.6
Davenport	606	71	79	29.27	29.96	− .14	29.6	+ 2.4	60	3	37	− 7	28	23	30	27	24	81	1.19	− 0.5	9	6,393	w.	33	sw.	13	6	9	16	6.5	6.9	0.9
Des Moines	861	84	97	29.00	29.94	− .17	28.8	+ 3.1	55	11	36	− 6	28	22	35	26	22	78	1.38	+ 0.1	5	5,917	nw.	28	w.	14	6	9	16	6.5	8.8	0.8
Dubuque	698	81	96	29.18	29.96	− .14	27.3	+ 2.8	55	13	34	− 9	28	21	24	26	23	85	0.96	− 0.8	8	5,277	nw.	27	nw.	14	4	10	17	7.1	5.6	1.5
Keokuk	614	64	78	29.28	29.98	− .14	32.8	+ 3.4	63	3	40	− 3	28	25	31	29	24	73	0.61	− 1.3	6	7,094	w.	37	nw.	14	6	12	13	6.5	2.1	0.0
Cairo	356	87	93	29.64	30.03	− .12	40.2	+ 1.7	64	12	47	14	28	33	22	36	32	74	5.10	+ 1.8	8	8,138	s.	42	w.	13	8	9	14	6.3	0.4	0.0
Peoria	609	11	45	29.29	29.97	− .14	30.8	+ 2.7	58	13	38	− 6	28	23	27	.....	.....	.....	1.87	− 0.5	8	6,547	w.	33	w.	14	6	11	14	6.4	4.6	0.3
Springfield, Ill.	644	10	91	29.28	29.97	− .15	32.6	+ 1.3	59	13	40	− 1	28	26	29	30	28	84	2.99	+ 0.6	8	7,527	w.	33	sw.	13	7	10	14	6.5	7.5	T.
Hannibal	534	74	109	29.40	29.99	− .13	34.0	+ 2.7	62	3	42	0	28	26	30	.....	.....	.....	0.96	− 0.7	6	7,806	w.	34	sw.	13	8	9	14	6.4	1.6	0.0
St. Louis	567	265	303	29.37	29.99	− .14	37.5	+ 2.0	64	2	45	5	28	30	28	33	28	72	2.41	+ 0.2	8	11,946	s.	48	w.	15	9	9	13	5.8	3.4	0.0
Missouri Valley.							29.6	+ 3.2										78	1.00	0.0										5.3		
Columbia, Mo.	781	11	84	29.13	29.99	− .13	35.9	+ 3.0	68	12	44	− 1	28	28	36	.....	.....	.....	1.33	− 0.7	9	7,757	w.	36	nw.	15	10	7	14	6.0	2.2	0.0
Kansas City	963	161	181	28.92	29.98	− .14	35.8	+ 4.3	64	12	44	4	24	28	33	31	26	70	0.89	− 0.5	4	10,395	nw.	46	nw.	15	14	8	9	5.0	0.7	0.0
St. Joseph	967	11	49	28.89	29.96	.....	33.2	.....	61	12	41	0	24	25	35	29	25	74	0.87	.....	3	7,719	nw.	42	nw.	15	11	7	13	5.2	1.2	0.0
Springfield, Mo.	1,324	98	104	28.57	30.00	− .13	38.1	+ 2.6	67	12	46	7	27	30	28	33	28	78	1.84	− 0.8	8	9,925	se.	43	se.	21	13	7	11	5.0	1.6	0.0
Iola	984	11	50	28.92	29.99	− .13	37.0	+ 4.5	66	12	46	6	24	28	30	.....	.....	.....	0.89	0.0	6	6,535	s.	28	nw.	15	9	9	13	6.0	T.	0.0
Topeka	987	92	107	.....	.....	.....	34.8	.....	64	3	44	2	24	26	35	.....	.....	.....	1.41	+ 0.6	4	8,826	s.	35	n.	16	9	11	11	5.7	5.3	0.0
Drexel	1,299	10	53	28.53	29.96	.....	26.0	.....	52	5	34	−18	24	18	41	23	21	86	1.21	.....	3	8,900	nw.	41	nw.	16	11	8	12	5.6	8.3	T.
Lincoln	1,189	11	84	28.66	29.97	− .15	29.2	+ 2.3	56	10	37	− 8	24	22	37	26	22	80	0.46	− 0.2	4	7,694	nw.	51	nw.	15	10	10	11	5.6	3.3	0.0
Omaha	1,105	115	122	28.76	29.98	− .13	28.7	+ 1.6	55	5	36	− 8	24	22	36	25	21	77	0.81	− 0.1	4	6,966	nw.	40	nw.	14	12	7	12	5.2	7.3	1.6
Valentine	2,598	47	54	27.18	30.00	− .10	24.8	+ 0.3	61	2	36	−20	24	14	40	21	16	75	0.87	+ 0.2	5	7,692	w.	49	nw.	14	13	12	6	4.4	13.1	1.0
Sioux City	1,135	94	164	28.72	29.98	− .11	24.8	+ 2.2	49	11	32	−11	24	18	36	22	20	83	1.40	+ 0.7	3	9,723	nw.	55	nw.	15	7	10	14	6.3	14.2	2.0
Huron	1,306	59	74	28.54	29.99	− .11	22.0	+ 7.3	48	3	31	−19	24	13	37	19	16	80	0.73	+ 0.1	6	7,095	nw.	38	nw.	14	10	11	10	5.0	7.3	1.5
Pierre	1,572	70	75	28.25	29.98	− .12	24.9	+ 4.8	55	10	35	−16	24	15	52	21	16	72	0.21	− 0.3	4	6,442	nw.	48	nw.	14	10	7	14	5.4	3.3	T.
Yankton	1,233	49	57	28.61	29.98	− .13	24.2	+ 2.0	51	11	32	−15	24	16	51	.....	.....	.....	1.13	+ 0.4	4	6,664	nw.	42	nw.	16	9	8	14	6.3	11.8	1.0

TABLE I.—*Climatological data for Weather Bureau stations, December, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F		° F	° F		° F	° F	° F	° F	%	In.	In.		Miles								0–10	In.	In.
Northern Slope.							**24.9**	**+ 0.9**										**69**	**0.75**	**− 0.1**										**6.1**		
Billings	3,140	5																														
Havre	2,505	11	44	27.22	29.94	− .11	22.6	+ 1.4	52	4	32	−28	23	13	59	20	15	75	1.01	+ 0.4	7	6,188	sw.	36	w.	31	6	9	16	7.0	10.1	4.4
Helena	4,110	87	112	25.66	29.96	− .17	28.3	+ 3.5	52	30	35	2	23	21	28	25	18	64	0.24	− 0.6	8	5,698	sw.	47	sw.	31	2	9	20	7.7	2.6	0.0
Kalispell	2,973	48	56		29.94	− .13	27.9	+ 4.0	47	30	33	5	15	23	24				1.23	− 0.6	15	3,412	nw.	34	sw.	30	1	5	25		10.3	T.
Miles City	2,371	26	48																													
Rapid City	3,259	50	58	26.48	30.01	− .08	27.8	+ 1.8	59	30	38	−14	22	18	40	22	14	59	0.32	− 0.1	6	6,752	w.	44	nw.	14	6	9	16	6.4	3.2	0.0
Cheyenne	6,088	84	101	23.85	29.97	− .12	27.9	− 1.1	60	1	37	− 1	22	19	35	23	18	68	0.57	+ 0.3	6	12,079	w.	58	w.	13	9	12	10	5.5	6.2	T.
Lander	5,372	60	68	24.53	30.11	− .04	16.0	− 3.2	52	30	28	−19	23	4	38	12	4	64	0.79	+ 0.1	4	2,995	sw.	38	sw.	11	16	10	5	4.3	9.3	3.6
Sheridan	3,790	10	47	25.98	30.01		24.6		54	30	37	−15	27	13	47	20	15	74	0.52		7	3,856	nw.	38	nw.	14	12	11	8	4.7	5.1	0.6
Yellowstone Park	6,200	11	48	23.75	30.05	− .11	21.7	+ 0.1	48	1	29	− 8	15	14	32	19	14	74	1.26	− 0.6	17	5,859	s.	42	sw.	10	2	8	21	7.8	14.4	8.6
North Platte	2,821	11	51	27.00	30.04	− .06	27.0	+ 0.4	62	1	38	−17	24	16	40	21	16	75	0.60	+ 0.1	4	5,423	w.	31	n.	12	11	9	11	5.3	5.3	T.
Middle Slope.							**34.8**	**+ 1.9**										**70**	**0.89**	**0.0**										**5.1**		
Denver	5,292	106	113	24.60	29.98	− .10	31.5	− 0.7	66	1	42	0	23	21	35	26	17	59	0.45	− 0.2	6	6,062	s.	42	w.	31	11	12	8	5.1	7.2	T.
Pueblo	4,685	80	86	25.17	29.95	− .13	33.8	+ 2.1	67	1	48	− 5	24	20	51	26	17	57	0.38	− 0.8	4	5,467	nw.	42	nw.	13	9	15	7	5.3	1.5	0.0
Concordia	1,392	50	58	28.48	30.00	− .11	32.1	+ 2.6	55	10	41	− 2	24	24	40	28	24	80	0.58	+ 0.1	3	6,613	nw.	41	nw.	15	7	9	15	6.5	2.7	0.0
Dodge City	2,509	11	51	27.34	30.01	− .09	35.1	+ 3.5	62	30	46	4	24	24	44	28	24	75	0.81	+ 0.2	5	8,015	nw.	34	nw.	21	14	10	7	4.3	0.2	0.0
Wichita	1,358	139	158	28.52	29.99	− .12	35.8	+ 1.6	61	5	44	5	27	28	25	32	27	74	1.76	+ 1.0	4	10,682	s.	42	nw.	13	9	16	6	4.9	T.	0.0
Altus	1,410	5					41.8		73	12	54	12	15	29	44				0.70		4		se.				22	2	7		0.2	0.0
Broken Arrow	765	11	52	29.16	30.00		40.3		71	12	50	12	27	31	31	35	31	77	1.67		7	10,721	s.	52	se.	21	12	10	9	4.9	T.	0.0
Muskogee	652	4					42.5		74	31	53	15	24	32	34				2.23		7		e.				13	11	7		0.0	0.0
Oklahoma City	1,214	10	47	28.70	30.01	− .10	40.8	+ 2.2	70	3	50	12	27	31	35	34	29	60	1.37	− 0.4	4	11,531	s.	44	nw.	13	12	13	6	4.4	T.	0.0
Southern Slope.							**44.6**	**+ 0.8**										**55**	**0.33**	**− 0.5**										**3.2**		
Abilene	1,738	10	52	28.18	30.02	− .09	46.8	+ 1.8	77	12	59	19	22	34	42	37	27	55	0.63	− 0.5	3	8,645	s.	38	sw.	25	19	9	3	3.0	0.0	0.0
Amarillo	3,676	10	49	26.18	29.98	− .11	39.0	+ 2.6	71	1	52	11	24	26	45	31	25	68	0.64	− 0.2	4	9,100	sw.	37	sw.	24	14	13	4	4.5	5.7	0.0
Del Rio	944	64	71	29.06	30.06	− .04	52.0	− 0.4	80	12	65	26	28	39	41				0.06	− 0.8	2	6,492	se.	46	nw.	12	18	11	2	3.4	0.0	0.0
Roswell	3,566	75	85	26.32	29.99	− .08	40.6	− 0.6	72	2	57	10	24	24	51	30	16	43	T.	− 0.6	0	6,157	nw.	42	nw.	12	25	6	0	2.0	0.0	0.0
Southern Plateau.							**42.6**	**− 2.2**										**49**	**0.23**	**− 0.4**										**2.5**		
El Paso	3,762	110	133	26.19	30.02	− .01	43.4	− 1.4	71	2	57	19	24	30	37	33	18	40	T.	− 0.5	0	8,261	w.	54	nw.	12	25	5	1	1.5	T.	0.0
Santa Fe	7,013	57	66	23.17	30.05	− .01	27.4	− 2.9	54	1	38	4	27	17	28	21	15	66	0.84	+ 0.1	6	4,997	n.	29	n.	27	14	12	5	3.8	12.2	T.
Flagstaff	6,908	10	59																													
Phoenix	1,108	76	81	28.84	30.03	− .01	49.7	− 2.2	75	1	65	28	24	34	40	38	24	41	T.	− 0.6	0	3,383	e.	24	w.	19	19	10	2	2.5	0.0	0.0
Yuma	141	9	54	29.90	30.06	+ .01	52.4	− 3.3	71	31	66	32	21	39	35	41	29	46	T.	− 0.4	0	3,931	n.	28	w.	19	28	3	0	1.1	0.0	0.0
Independence	3,957	9	41	25.99	30.09	− .03	40.2	− 1.4	69	27	53	21	13	27	38	31	21	52	0.32	− 0.5	4	3,852	nw.	30	se.	11	15	11	5	3.8	0.0	
Middle Plateau.							**30.1**	**− 1.1**										**71**	**0.72**	**− 0.2**										**6.1**		
Reno	4,532	74	81	25.45	30.08	− .07	34.0	+ 0.3	58	29	43	11	5	25	29	30	26	74	0.99	− 0.7	10	4,643	w.	42	w.	24	10	10	11	5.6	7.7	0.0
Tonopah	6,090	12	20	24.05	30.11		31.8		50	1	39	13	5	25	29	27	19	61	0.16	− 0.6	5	8,119	se.	48	w.	11	11	11	9	5.3	3.2	0.0
Winnemucca	4,344	18	56	25.61	30.09	− .09	31.2	+ 0.6	52	1	40	6	5	22	27	28	24	76	1.17	+ 0.2	12	5,550	sw.	54	sw.	11	6	7	18	6.9	10.3	0.0
Modena	5,479	10	43	24.58	30.08	− .04	27.6	− 4.1	57	29	40	1	15	15	38	22	16	67	0.25	− 0.3	4	7,263	w.	50	s.	11	14	12	5	4.3	2.3	0.0
Salt Lake City	4,360	163	203	25.62	30.08	− .07	31.7	− 0.4	49	1	38	12	15	25	21	29	24	73	1.38	0.0	21	4,833	nw.	50	w.	11	2	5	24	8.3	17.8	1.6
Grand Junction	4,602	60	68	25.39	30.07	− .03	26.2	− 2.0	47	4	36	0	27	16	29	23	16	76	0.38	− 0.1	9	3,090	nw.	24	nw.	11	7	8	16	6.4	3.7	0.5
Northern Plateau.							**34.2**	**+ 2.0**										**78**	**1.88**	**+ 0.2**										**8.2**		
Baker	3,471	48	53	26.39	30.05	− .11	30.6	+ 3.2	48	30	37	8	14	24	22	28	25	81	1.21	− 0.3	16	4,633	se.	34	s.	10	3	4	24	7.8	6.3	T.
Boise	2,739	78	86	27.17	30.09	− .11	34.3	+ 2.1	54	30	40	16	15	28	21	32	28	76	2.43	+ 0.7	18	3,820	nw.	31	nw.	30	3	7	21	7.8	4.9	0.0
Lewiston	757	40	48	29.16	29.99	− .14	38.2	+ 0.7	60	30	44	26	23	33	18				1.31	+ 0.2	12	3,157	e.	40	w.	30	1	5	25	8.8	0.1	0.0
Pocatello	4,477	60	68	25.43	30.07	− .12	28.6	+ 0.2	51	1	35	4	6	22	25	26	22	76	1.26	+ 0.4	15	8,378	se.	42	sw.	31	2	5	24	8.0	13.1	T.
Spokane	1,929	101	110	27.88	29.97	− .11	34.0	+ 2.0	51	30	38	19	26	30	17	32	30	83	2.59	0.0	19	5,395	sw.	36	sw.	30	2	3	26	8.5	5.3	0.0
Walla Walla	991	57	65	28.90	29.99	− .13	39.8	+ 3.8	62	30	46	22	15	34	24	36	32	76	2.50	+ 0.4	14	4,597	s.	42	w.	30	2	4	25	8.4	5.2	0.0
North Pacific Coast Region.							**43.6**	**+ 1.5**										**85**	**8.49**	**+ 0.8**										**9.3**		
North Head	211	11	56	29.65	29.88	− .15	44.7	+ 0.4	54	16	48	34	14	41	13	43	41	84	11.39	+ 3.9	29	17,624	se.	73	s.	3	0	3	28	9.5	T.	0.0
Port Angeles	29	8	53	29.83	29.86		41.2		54	3	46	28	14	37	21				4.73	− 0.4	21	3,945	s.	31	w.	13	0	1	30	9.7	T.	0.0
Seattle	125	215	250	29.78	29.91	− .10	43.4	+ 2.2	53	3	47	31	14	40	14	41	38	83	5.68	− 0.4	24	8,310	se.	46	sw.	30	0	3	28	9.5	0.0	0.0
Tacoma	213	113	120	29.68	29.92	− .09	42.6	+ 2.3	55	3	47	28	14	38	16	42	41	91	7.23	− 0.1	26	5,216	sw.	36	sw.	12	0	4	27	8.9	0.0	0.0
Tatoosh Island	86	7	57	29.70	29.80	− .16	44.4	+ 0.5	54	1	47	38	9	42	8	43	41	86	14.90	+ 0.3	31	15,412	e.	72	s.	3	0	1	30	9.8	0.0	0.0
Yakima	1,071	4																														
Medford	1,425	4																														
Portland, Oreg.	153	68	106	29.80	29.96	− .11	44.1	+ 2.8	58	29	48	31	14	40	16	42	38	81	8.32	+ 1.0	27	5,614	se.	32	sw.	10	0	3	28	9.3	0.1	0.0
Roseburg	510	9	57	29.47	30.02	− .09	42.7	+ 0.8	61	29	48	27	15	37	23	41	39	87	7.17	+ 1.2	24	2,359	s.	22	w.	23	0	7	24	8.4	0.0	0.0
Middle Pacific Coast Region.							**47.3**	**− 1.3**										**83**	**6.52**	**+ 2.1**										**6.2**		
Eureka	62	73	80	30.02	30.08	− .04	48.4	+ 0.4	67	15	54	35	5	43	27	47	45	87	10.89	+ 3.6	23	5,309	se.	40	nw.	11	2	6	23	8.4	0.0	0.0
Mount Tamalpais	2,375	11	18	27.60	30.11	− .01	43.0	− 4.6	56	28	48	32	9	38	17				6.88	+ 3.0	21	16,249	nw.	70	sw.	11	7	7	17	6.6	0.0	0.0
Point Reyes Light	490	7	18	29.54	30.06		49.8	− 0.8	60	14	53	42	19	46	15				5.64		18	17,153	nw.	80	s.	19	9	10	12	5.8	0.0	0.0
Red Bluff	332	50	56	29.73	30.10	− .04	44.8	− 1.6	63	26	51	32	20	38	24	43	39	81	5.97	+ 1.5	18	4,488	nw.	25	se.	11	11	10	10	5.5	0.0	0.0
Sacramento	69	106	117	30.04	30.11	− .03	45.4	− 0.9	58	1	51	34	20	40	18	45	43	90	4.32	+ 0.8	16	5,238	se.	36	s.	11	11	6	14	5.4	0.0	0.0
San Francisco	155	208	243	29.93	30.10	− .02	51.0	− 0.1	61	29	56	42	26	46	16	47	42	75	7.48	+ 3.2	16	6,263	se.	41	s.	19	11	6	14	5.8	0.0	0.0
San Jose	141	12	110	29.98	30.13		48.4	− 1.5	65	6	57	32	13	40	32				3.58	+ 0.5	16	4,852	se.	34	e.	9	11	5	15	5.9	0.0	0.0
South Pacific Coast Region.							**52.6**	**− 0.4**										**72**	**1.62**	**− 0.6**										**4.6**		
Fresno	327	89	98	29.77	30.14	+ .01	47.5	+ 0.7	64	17	55	32	5	40	27	44	40	79	1.07	− 0.5	13	4,123	nw.	31	nw.	19	12	6	13	5.3	0.0	0.0
Los Angeles	338	159	191	29.71	30.08	+ .01	55.8	− 0.7	75	14	64	41	21	48	25	48	41	65	1.01	− 1.9	6	4,341	ne.	30	nw.	20	15	7	9	4.1	0.0	0.0
San Diego	87	62	70	29.97	30.06	− .01	54.8	− 0.9	72	15	63	40	21	47	25	49	45	74	0.54	− 1.3	5	3,976	nw.	33	w.	19	13	13	5	4.3	0.0	0.0
San Luis Obispo	201	32	40	29.89	30.11	.00	52.2	− 0.6	72	27	62	31	6	42	32	46	41	72	3.85	+ 1.5	13	2,915	n.	23	nw.	19	13	9	9	4.5	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.93	30.02		75.8		83	20	81	67	12	71	14				5.30	− 0.8	23	8,588	e.	48	e.	24	10	15	6	4.8	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.71	29.83	− .01	80.4	+ 0.5	90	20	88	71	13	73	17	74	73	83	1.94	− 2.1	13	5,508	nw.	26	n.	16	3	22	6	6.1	0.0	0.0
Colon	36	7	97	29.80	29.84	− .01	81.4	+ 1.7	88	6	86	73	13	77	12	76	74	79	2.06	− 9.4	20	9,414	n.	28	ne.	30	7	13	11	6.1	0.0	0.0
Alaska.																																
Juneau	80	11	40				31.1		46	18	35	13	25	27	17	29	24	76	6.01		14	3,771	se.	20	ne.	3	4	7	20	7.5	35.0	6.7

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1920, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	20			0.44														0.44			
Albany, N. Y.	14			1.61														0.55			
Alpena, Mich.	22			1.29														(*)			
Amarillo, Tex.	6			0.52														(*)			
Anniston, Ala.	13	4:10 a.m.	7:10 p.m.	3.91	5:46 p.m.	6:09 p.m.	3.09	0.14	0.28	0.44	0.53	0.65									
Asheville, N. C.	13			1.86														0.35			
Atlanta, Ga.	22			1.06														0.46			
Atlantic City, N. J.	14			1.23														0.40			
Augusta, Ga.	22			0.63														0.37			
Baker, Oreg.	19–20			0.35														(*)			
Baltimore, Md.	1			1.48														0.49			
Bentonville, Ark.	20			0.37														0.25			
Binghamton, N. Y.	14			0.97														0.28			
Birmingham, Ala.	13	D. N. a.m.	2:25 p.m.	3.68	1:15 p.m.	1:58 p.m.	2.18	0.12	0.24	0.47	0.59	0.70	0.88	1.15	1.36	1.46					
Bismarck, N. Dak.	31			0.15														(*)			
Block Island, R. I.	22–23	9:40 p.m.	5:10 a.m.	1.72	2:35 a.m.	3:30 a.m.	0.71	0.06	0.11	0.17	0.21	0.26	0.37	0.49	0.66	0.75	0.83	0.93			
Boise, Idaho.	30			0.51														0.17			
Boston, Mass.	14			1.01														0.23			
Buffalo, N. Y.	15			0.58														(*)			
Burlington, Vt.	5–6			1.36														(*)			
Cairo, Ill.	4			0.81														0.39			
Canton, N. Y.	5–6			1.24														(*)			
Charles City, Iowa.	13			0.89														(*)			
Charleston, S. C.	27			1.58														0.43			
Charlotte, N. C.	7			0.95														0.36			
Chattanooga, Tenn.	22			2.33														0.53			
Cheyenne, Wyo.	20			0.35														(*)			
Chicago, Ill.	13			0.80														0.22			
Cincinnati, Ohio.	21			0.38														0.17			
Cleveland, Ohio.	22			0.32														(*)			
Columbia, Mo.	13			0.32														0.16			
Columbia, S. C.	22			0.64														0.33			
Columbus, Ohio.	13			0.36														0.18			
Concord, N. H.	14			2.00														(*)			
Concordia, Kans.	13			0.29														(*)			
Corpus Christi, Tex.	5			0.17														(*)			
Dallas, Tex.	21			0.47														0.44			
Davenport, Iowa.	25–26			0.48														(*)			
Dayton, Ohio.	4			0.28														0.09			
Del Rio, Tex.	20			0.04														0.02			
Denver, Colo.	5–6			0.21														(*)			
Des Moines, Iowa.	13			0.89														(*)			
Detroit, Mich.	4–5			0.94														(*)			
Devils Lake, N. Dak.	10–11			0.14														(*)			
Dodge City, Kans.	20			0.11														0.09			
Drexel, Nebr.	20–21			1.20														(*)			
Dubuque, Iowa.	21			0.25														(*)			
Duluth, Minn.	13			0.38														(*)			
Eastport, Me.	14–15			0.78														(*)			
Elkins, W. Va.	22–23			0.57														(*)			
Ellendale, N. Dak.	20–21			0.11														(*)			
El Paso, Tex.	20			T.														T.			
Erie, Pa.	1			0.62														(*)			
Escanaba, Mich.	13			0.68														0.18			
Eureka, Calif.	9			1.16														0.44			
Evansville, Ind.	21			1.53														0.24			
Flagstaff, Ariz.																					
Fort Smith, Ark.	20			0.63														0.42			
Fort Wayne, Ind.	4			1.09														(*)			
Fort Worth, Tex.	20–21	11:15 a.m.	D. N. a.m.	0.67	12:20 a.m.	12:40 a.m.	0.10	0.08	0.14	0.35	0.52										
Fresno, Calif.	9			0.22														0.18			
Galveston, Tex.	4	D. N. a.m.	D. N. a.m.	0.85	4:26 a.m.	4:42 a.m.	0.11	0.18	0.49	0.66	0.69										
	5–6	6:32 p.m.	6:37 a.m.	3.39	12:08 a.m.	1:28 a.m.	1.27	0.10	0.23	0.39	0.46	0.52	0.72	0.82	1.02	1.15	1.25	1.71			
Grand Haven, Mich.	4			0.95														0.25			
Grand Junction, Colo.	19–20			0.20														(*)			
Grand Rapids, Mich.	13			0.50														0.20			
Green Bay, Wis.	13–14			0.64														(*)			
Greenville, S. C.	14			0.42														0.40			
Hannibal, Mo.	13			0.57														0.24			
Harrisburg, Pa.	14			1.27														0.36			
Hartford, Conn.	5			2.24														0.59			
Hatteras, N. C.	8	4:12 p.m.	7:35 p.m.	0.58	5:38 p.m.	5:50 p.m.	0.05	0.14	0.38	0.52											
	22–23	4:30 p.m.	D. N. a.m.	1.01	7:38 p.m.	7:55 p.m.	0.16	0.09	0.27	0.69	0.71										
Havre, Mont.	31			0.44														(*)			
Helena, Mont.	30			0.09														0.08			
Houghton, Mich.	14–15			1.31														(*)			
Houston, Tex.	21	12:35 p.m.	3:15 p.m.	1.10	12:40 p.m.	1:05 p.m.	0.01	0.05	0.10	0.28	0.37	0.55									
Huron, S. Dak.	20–21			0.50														(*)			
Independence, Calif.	2			0.22														(*)			
Indianapolis, Ind.	13			0.85														0.42			
Iola, Kans.	20			0.52														0.26			
Jacksonville, Fla.	27			1.54														0.39			
Kalispell, Mont.	30			0.31														0.13			
Kansas City, Mo.	20			0.48														0.18			
Keokuk, Iowa.	13			0.28														(*)			
Key West, Fla.	7			0.20														0.17			
Knoxville, Tenn.	22			1.42														0.30			
La Crosse, Wis.	21			0.80														(*)			
Lander, Wyo.	5			0.40														(*)			
Lansing, Mich.	4			0.81														(*)			
Lewiston, Idaho.	4			0.24														0.13			
Lexington, Ky.	13			0.47														0.19			
Lincoln, Nebr.	20–21			0.42														(*)			
Little Rock, Ark.	26			1.41														0.49			
Los Angeles, Calif.	19			0.59														0.29			
Louisville, Ky.	13			0.65														0.19			
Ludington, Mich.	4			0.77														0.28			
Lynchburg, Va.	4			0.27														0.14			
Macon, Ga.	22	11:13 a.m.	7:00 p.m.	1.59	1:15 p.m.	1:24 p.m.	0.14	0.39	0.57												
Madison, Wis.	3			0.13														0.12			
Marquette, Mich.	13–14			0.71														(*)			

* Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Memphis, Tenn	21			2.44														0.47			
Meridian, Miss	13	D.N.a.m.	D.N.a.m.	1.90	2:36 a.m.	3:37 a.m.	0.25	0.07	0.10	0.17	0.26	0.41	0.44	0.50	0.73	0.94	1.05	1.23	1.34		
	13	1:00 p.m.	4:00 p.m.	1.02	1:04 p.m.	1:21 p.m.	0.01	0.36	0.56	0.68	0.72										
	21-22	9:40 p.m.	8:30 a.m.	3.40	9:52 p.m.	10:34 p.m.	0.03	0.10	0.35	0.52	0.72	0.93	1.05	1.14	1.28	1.34					
	26	2:05 p.m.	D.N.p.m.	1.36	4:52 p.m.	5:10 p.m.	0.12	0.28	0.43	0.48	0.53										
Miami, Fla	28			0.43														0.36			
Milwaukee, Wis	13-14			0.95														(*)			
Minneapolis, Minn	21			0.42														(*)			
Mobile, Ala	22			0.83														0.54			
Modena, Utah	19-20			0.14														(*)			
Montgomery, Ala	13	11:15 a.m.	6:30 p.m.	1.57	1:10 p.m.	1:37 p.m.	0.14	0.07	0.17	0.25	0.35	0.40	0.50								
	22	D.N.a.m.	12:15 p.m.	3.39	5:17 a.m.	5:34 a.m.	0.25	0.26	0.73	0.94	0.97										
					6:56 a.m.	7:43 a.m.	1.69	0.05	0.13	0.31	0.35	0.44	0.54	0.66	0.74	0.79	0.85				
Moorhead, Minn	31			0.31														(*)			
Mount Tamalpais, Calif	9			0.46														0.39			
Nantucket, Mass	14			0.78														0.35			
Nashville, Tenn	26			1.28														0.23			
New Haven, Conn	5			1.93														0.60			
New Orleans, La	22	3:50 a.m.	7:40 a.m.	1.03	5:56 a.m.	6:26 a.m.	0.10	0.10	0.34	0.45	0.56	0.70	0.76								
New York, N. Y	5			1.01														0.39			
Norfolk, Va	22			1.13														0.45			
Northfield, Vt	13-14			1.21														(*)			
North Head, Wash	10	6:42 a.m.	D.N.p.m.	1.38	3:49 p.m.	4:45 p.m.	0.42	0.05	0.10	0.16	0.26	0.45	0.53	0.57	0.60	0.65	0.74	0.88			
North Platte, Nebr	20-21			0.52														(*)			
Oklahoma City, Okla	6			1.04														0.26			
Omaha, Nebr	20-21			0.77														(*)			
Oswego, N. Y	1-2			1.16														(*)			
Palestine, Tex	21	D.N.a.m.	12:05 p.m.	1.87	5:17 a.m.	5:39 a.m.	0.04	0.09	0.22	0.39	0.57	0.65									
Parkersburg, W. Va	14			0.34														0.18			
Pensacola, Fla	22	9:10 a.m.	1:35 p.m.	1.74	10:18 a.m.	11:24 a.m.	0.03	0.13	0.42	0.60	0.69	0.77	0.91	1.04	1.11	1.22					
Peoria, Ill	13			1.06														0.54			
Philadelphia, Pa	22			1.11														0.59			
Phoenix, Ariz	12			T.														T.			
Pierre, S. Dak	20-21			0.18														(*)			
Pittsburgh, Pa	22			0.38														0.15			
Pocatello, Idaho	4-5			0.35														(*)			
Point Reyes Light, Calif	23			2.02														0.37			
Port Angeles, Wash	10			1.26														0.20			
Port Huron, Mich	4			0.94														0.20			
Portland, Me	5			0.80														0.26			
Portland, Oreg	10			1.26														0.29			
Providence, R. I	14			1.02														(*)			
Pueblo, Colo	3			0.18														(*)			
Raleigh, N. C	8			2.07														0.31			
Rapid City, S. Dak	20-21			0.17														(*)			
Reading, Pa	1			1.64														0.40			
Red Bluff, Calif	1			0.49														0.28			
Reno, Nev	1-2			0.29														(*)			
Richmond, Va	22			0.63														(*)			
Rochester, N. Y	1-2			0.67														(*)			
Roseburg, Oreg	9			1.06														0.26			
Roswell, N. Mex	6			T.														T.			
Sacramento, Calif	9			0.38														0.24			
Saginaw, Mich	14			0.26														0.20			
St. Joseph, Mo	20-21			0.52														(*)			
St. Louis, Mo	13	6:51 a.m.	10:40 a.m.	0.85	7:26 a.m.	7:41 a.m.	0.07	0.05	0.24	0.58											
St. Paul, Minn	21			0.55														(*)			
Salt Lake City, Utah	24-25			0.22														(*)			
San Antonio, Tex	5			0.05														0.04			
San Diego, Calif	19			0.33														(*)			
Sand Key, Fla	28			0.50														(*)			
Sandusky, Ohio	14			0.27														0.16			
Sandy Hook, N. J	23			0.46														0.46			
San Francisco, Calif	23			1.77														0.30			
San Jose, Calif	23			0.74														0.20			
San Luis Obispo, Calif	19			1.01														0.44			
Santa Fe, N. Mex	12			0.46														(*)			
Sault Ste. Marie, Mich	13-14			1.48														(*)			
Savannah, Ga	22			1.35														0.47			
Scranton, Pa	1			0.89														(*)			
Seattle, Wash	10			0.97														0.31			
Sheridan, Wyo	5			0.26														(*)			
Shreveport, La	21	6:40 a.m.	4:20 p.m.	3.39	7:52 a.m.	9:36 a.m.	0.03	0.05	0.13	0.30	0.36	0.42	0.52	0.59	0.64	0.99	1.18	1.39	1.59	2.04	2.12
Sioux City, Iowa	20-21			1.16														(*)			
Spokane, Wash	29-30			0.61														(*)			
Springfield, Ill	13			1.19														(*)			
Springfield, Mo	13			0.42														0.31			
Syracuse, N. Y	1-2			0.98														(*)			
Tacoma, Wash	10			0.87														0.38			
Tampa, Fla	22			0.39														0.26			
Tatoosh Island, Wash	27			1.67														0.25			
Taylor, Tex	21			0.61														0.43			
Terre Haute, Ind	4			1.37														0.32			
Thomasville, Ga	22	2:15 p.m.	10:22 p.m.	1.54	4:35 p.m.	5:25 p.m.	0.28	0.06	0.17	0.26	0.36	0.43	0.48	0.65	0.74	0.82	0.95				
	27	D.N.a.m.	11:38 a.m.	3.25	4:18 a.m.	5:21 a.m.	0.18	0.09	0.22	0.54	0.89	1.00	1.16	1.26	1.37	1.45	1.49	1.69	1.77		
Toledo, Ohio	1			0.69														0.15			
Tonopah, Nev	11			0.10														(*)			
Topeka, Kans	20-21			0.74														(*)			
Trenton, N. J	1			1.51														0.47			
Valentine, Nebr	20-21			0.69														(*)			
Vicksburg, Miss	21-22			3.97														(*)			
Walla Walla, Wash	28			0.52														(*)			
Washington, D. C	1			0.78														0.34			
Wausau, Wis	13-14			0.63														(*)			
Wichita, Kans	20			1.02														(*)			
Williston, N. Dak	19-20			0.10														(*)			
Wilmington, N. C	8			0.88														0.66			
Winnemucca, Nev	30			0.15														0.09			
Wytheville, Va	22			0.46														0.21			
Yankton, S. Dak	20-21			0.82														(*)			
Yellowstone Park, Wyo	10-11			0.34														(*)			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, December, 1920.*

Stations.	Altitude above mean sea level Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.44	29.58	−.25	28.5	−0.2	32.5	23.6	48	11	5.00	−0.03	24.0
Sydney, C. B. I.	48	29.77	29.82	−.07	30.2	+2.0	34.5	26.0	52	17	2.95	−1.68	11.5
Halifax, N. S.	88	29.73	29.84	−.12	30.1	+2.5	36.7	23.5	55	0	4.55	−0.57	4.6
Yarmouth, N. S.	65	29.78	29.85	−.13	32.6	+1.9	38.1	27.1	56	5	4.77	−0.27	13.0
Charlottetown, P. E. I.	38	29.78	29.82	−.12	26.5	+2.2	30.8	22.3	46	0	3.92	+0.26	11.5
Chatham, N. B.	28	29.85	29.89	−.05	21.2	+4.2	27.5	14.9	40	−15	6.46	+3.24	36.0
Father Point, Que.	20	29.92	29.95	00	18.0	+2.6	23.7	12.3	36	−16	4.24	+1.41	42.4
Quebec, Que.	296	29.60	29.94	−.13	19.6	+4.4	24.5	14.8	36	−21	3.66	−0.03	23.9
Montreal, Que.	187	29.71	29.93	−.10	22.1	+3.8	26.4	17.4	42	−8	6.54	+2.89	21.4
Stonecliffe, Ont.	489	29.32	29.96	−.05	14.6	−0.4	25.2	4.1	40	−26	2.13	−0.26	6.4
Ottawa, Ont.	236	29.67	29.95	−.07	21.3	+4.3	27.1	15.6	42	−8	4.44	+1.53	15.6
Kingston, Ont.	285	29.60	29.93	−.11	26.8	+3.1	32.3	21.4	49	1	2.30	−0.94	6.1
Toronto, Ont.	379	29.49	29.92	−.13	31.5	+4.5	36.6	26.3	51	10	3.04	+0.13	11.5
Cochrane, Ont.	930												
White River, Ont.	1,244	28.48	29.84	−.13	14.0	+4.3	22.7	5.2	41	−35	2.09	+0.38	13.5
Port Stanley, Ont.	592	29.25	29.91	−.16	32.0	+3.6	37.3	26.8	49	5	3.68	+1.26	9.7
Southampton, Ont.	656	29.13			30.1	+3.4	35.8	24.5	51	6	4.31	+0.23	23.5
Parry Sound, Ont.	688	29.20	29.92	−.09	25.0	+3.9	31.4	18.9	49	4	7.90	+3.42	51.0
Port Arthur, Ont.	644	29.16	29.89	−.10	20.8	+7.6	26.2	15.4	41	−13	3.21	+2.34	11.2
Winnipeg, Man.	760	29.08	29.95	−.07	11.6	+7.5	18.7	4.5	32	−22	0.78	−0.13	7.8
Minnedosa, Man.	1,690	28.03	29.93	−.09	8.8	+3.1	17.7	0.0	34	−30	0.55	−0.07	5.5
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.56	29.90	−.10	12.5	+5.1	19.5	5.5	38	−23	0.52	0.00	5.2
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.26	29.94	−.05	18.7	+2.7	28.2	9.2	49	−22	0.18	−0.60	1.8
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.31	29.96	−.05	9.7	+6.9	16.3	3.1	36	−20	0.45	−0.29	4.5
Battleford, Sask.	1,592	28.10	29.92	−.07	11.6	+6.2	18.5	4.8	40	−16	0.20	−0.12	2.0
Kamloops, B. C.	1,262	28.60	29.92	−.02	32.9	+4.0	37.4	28.4	48	16	0.82	+0.04	8.0
Victoria, B. C.	230	29.58	29.84	−.13	42.5	+1.3	45.5	39.6	51	32	4.62	−3.36	
Barkerville, B. C.	4,180	25.35	29.73	−.15	21.2	+0.3	27.2	15.3	36	−5	3.65	+0.48	36.5
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Bermuda	151	29.94	30.10	−.02	66.0	+1.3	71.2	60.7	75	54	4.55	+0.00	

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Feb. 2, 1921.]

TABLE 1.—*Noninstrumental earthquake reports, December, 1920.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1920.	H. m.		° ′	° ′			Sec.			
1	1 30	Maricopa	35 05	119 23	4	1	10	None	Felt by many	E. F. Foulke.
		Taft	35 15	119 30	5	1		do	do	Associated Press.
4	11 55	Los Alamos	34 45	120 15	4	1	Long.	do		H. R. Gewe.
5	12 03	Maricopa	35 05	119 23	4	1	10	do	Felt by many	E. F. Foulke.
		Ojai	34 25	119 12	5	1	1	Faint	do	W. H. Duncan.
		Santa Barbara	34 23	119 40	5	1	10 *ca.*	None	Felt by everyone	A. W. Mutter.
6	20 25	Los Angeles	34 03	118 15	3	3	1	Rattling	Felt by many	R. F. Young.
13	17 37	Lone Pine	36 37	118 01	4	1	Several.	Rumbling	Felt by several	G. F. Marsh.
15	3 45	El Cajon	32 48	116 58	3	1	Few.	None	do	E. P. Kissler.
	3 57	San Diego	32 43	117 10						Associated Press.
18	17 26	Hemet	33 45	116 45	5	2	10	Loud	Felt by many	C. E. McManigal.
	20 30	Spreckels	36 35	121 38	3	1	2		do	S. I. Gleason.
19	12 15	Spreckels	36 35	121 38	3	2	3, 2		During thunderstorm	Do.
20	4 30	Brawley	32 59	115 40	4	2	5	Rumbling	Felt by many	M. D. Witter.
	5 15	Amos	33 05	115 16	5	2	Few.	do	do	R. H. Freeman.
		Blythe	33 35	114 45	3			None	do	W. J. Custer.
	5 31	Calexico	32 41	115 30	2	1	15	do	do	W. S. Pratt.
	14 46	Calexico	32 41	115 30	3	1	45	do	do	Do.
	15 10	Amos	33 05	115 16	3	1	Few.	do	do	R. H. Freeman.
	15 15	Blythe	33 35	114 45	3			do	do	W. J. Custer.
	15 45	Brawley	32 50	115 40	7				Shocks throughout day; felt heavily at Westmoreland also.	M. D. Witter.
21	14 48	Calexico	32 41	115 30	3	1	30			W. S. Pratt.
	15 00	Amos	33 05	115 16	4	1	Few.	do	do	R. H. Freeman.
	15 15	Blythe	33 35	114 45	4	1	Short.	do	do	W. J. Custer.
	15 40	Blythe	33 35	114 45	4	1	do	do	do	Do.
	19 55	Salinas	36 36	121 40	3	1	3	do	Felt by many	E. D. Eddy.
	19 56	Spreckels	36 35	121 38	4	3	5, 7, 8		do	S. I. Gleason.
22	4 18	Spreckels	36 35	121 38	4	1	5	Rattling	do	Do.
28	1 55	Los Angeles	34 03	118 15	3	2	1	None	Felt by several	R. F. Young.
		COLORADO.								
29	2 50	New Castle	39 30	107 30	5	1	5–10	None		M. L. Wellen.
	3 00	New Castle	39 30	107 30	4	2	3–4	Rumbling		Mrs. Cliff.
		Glenwood Springs	39 30	107 15	Light.	1	2	Faint	Felt by many	Mrs. C. M. Keen.
30	9 50	New Castle	39 30	107 30	5					M. L. Wellen.
30	17 50	New Castle	39 30	107 30	5					Do.
		OREGON.								
15	18 50	Cascadia	44 15	122 30	3	1		Loud report	Felt by everyone	G. M. Geissendorfer.
		TENNESSEE.								
24	? ?	Crossville	36 00	85 00	5	2	60	Rumbling	No damage	J. E. Converss.
	8 *ca.*	Decatur	35 32	84 50	2				Awakened a few	J. W. Linard.
	8 30	Glen Alice	35 50	84 50	5	1		Rumbling		J. C. Owings.
	8 40	Spring City	35 40	84 50	3	1	60	do		A. D. Paul.
	8 30	Rockwood	35 50	84 40		1	3 min.	None	Felt by many	Mary E. Mason.
		LATE REPORTS.								
		OREGON.								
Nov. 9	20 30	Astoria	46 10	123 50	Weak.				Felt by several	C. C. Rosenberg.
28	11 45	Astoria	46 10	123 50	4	1			do	Do.

TABLE 2.—*Instrumental reports, December, 1920.*

[For significance of symbols and abbreviations, and for a description of stations and instruments, see the REVIEW for January, 1920, pp. 62-63.]

ALABAMA. *Spring Hill College, Mobile.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	Sec.	μ	μ	Km.	
Dec. 16		S_N	0 35 50				12000?	Instrument undamped.
		L_E	0 57 20					
		L_N	1 00 20					
		M_E	1 06 00	25	*9,000			
		M_N	1 14 30	20		*12,000		
		F	2 30 00					

* Trace amplitude.

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 16		e_N	12 17 31					Record lost between 12:45:44 and 12:52:22, including M and probably C. E-W not operating.
		e_N	12 27 01					
		L_N	12 39 14	55				
		M_N	12 45 44			8,380		
		F_N	13 33 ..					

TABLE 2.—*Instrumental reports, December, 1920*—Continued.

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 10		e_E	4 44 10					No record on N-S.
		L_E	5 00 00	30				
		M_E	5 08 35	15	40			
		C_E	5 11 ..	15				
		F_E	5 59 ..					
11		e_E	21 30 54					Record difficult to interpret.
		e_N	21 36 27					
		e_E	21 36 52					
		eL_E	21 38 15					
		eL_N	21 39 20					
		M_E	21 40 15	16	20			
		M_N	21 40 20	16		10		
		C_N	21 41 ..					
		C_E	21 42 ..					
		F_N	21 46 ..					
		F_E	21 51 ..					
16		e_N	12 24 16					
		e_E	12 24 19					
		e_E	12 31 48					
		i_E	12 39 10					
		e_N	12 39 40					
		L_N	12 49 30	70				
		L_E	12 49 30	75				
		M_E	13 05 00	18	2,280			
		M_N	13 11 11	22		440		
		C_N	13 13 ..	20				
		C_E	13 16 ..	17				
		F_N	13 58 ..					
		F_E	14 50 ..					
20		P_N	14 47 42					
		eP_E	14 47 54					
		M_E	14 49 00	4	40	10		
		L	14 55 ..					

CALIFORNIA. *Theosophical University, Point Loma.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 5			15 00 00		100	100		Tremors during 24 hours preceding this time.
12			15 00 00		100	100		
15			3 57 00		300	300		Light shock.
28			15 00 00		150	150		Tremors as above.
29			15 00 00		200	200		Do.
30			15 00 00		150	150		Do.
31			15 00 00		100	100		Do.

COLORADO. *Sacred Heart College, Denver.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 5–6.								Activity at intervals on N–S component.
9		L_N	2 40 ..					Very small waves.
		F_N	2 55 ..					
16		P	12 29 ..					S not visible.
		L_N	12 55 ..	31		*3,000		
		L_E	12 53 ..	33	*4,000			
		M_N	12 57 ..	29		*8,500		
		M_E	12 58 ..	27	*13,000			
		C	13 26 ..	22–25				
		F	14 00 ..					
25								Wavelets at intervals during day, especially on N–S.
31		P_N	21 28 ..					Hardly any record on E–W.
		L_N	21 33 ..					
		M_N	21 49 ..					
		F_N	22 05 ..					

* Trace amplitude.

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 10		e	4 38 ..					Very heavy micros.
		S_N	4 47 44					
		eL_E	5 04 00	32				
		eL_N	5 05 18	27				
		L_E	5 07 ..	27				
		L_N	5 10 ..	22				
		F	6 *ca.*					
11		e_E	21 28 ..					Heavy micros.
		e_N	21 27 11					
		S_N	21 33 44					
		eL_N	21 38 42					
		F	22 15 ..					
13		e_N?	4 17 11					Very heavy micros.
		L_E	4 41 ..	30				
		L_N	4 42 ..	30				
		F	5 20 ..					
16		eP_E	12 24 32					Heavy micros.
		eP_N	12 24 26					
		S_N	12 30 47					Se not discernible.
		eL	12 39 36					
		L	12 52 ..	28				
		M_E1	12 59 46	30	*10,500			P possibly sooner.
		M_N1	13 09 ..	22		*9,300		
		M_N2	13 12 21	24		*13,700		
		M_E3	13 10 ..	24	*9,200			
		M_E2	13 05 ..	24	*14,100			
		F	16 *ca.*					
			VERTICAL.					
		eP_Z	*12 24 29*					Heavy micros.
		S_Z	*12 30 24*					
		eL_Z	*12 39 30*	*22*				
		M_Z1	*13 09 ..*	*22*	**5,700*			
		M_Z2	*13 13 21*	*19*	**6,200*			
		F	*15 30 ..*					
17		eP_E	19 11 20					Very heavy micros.
		eP_N?	19 11 20					
		S_E	19 20 43					
		S_N?	19 20 38					
		eL_N	19 40 06	10				
		L_N	19 43 25	25				
		F	20 20 ..					
25		L_E	12 27 16	22				Heavy micros.
		L_N	12 30 ..	22				
		F	12 55 ..					

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 10		P	4 37 58				8,400	
		S	4 47 38					
		eL	5 03 20					
		L	5 25 ..	18				
		F	5 50 ..					
11		P	21 28 19				3,600	
		S	21 33 43					
		eL	21 38 35					
		F	21 55 ..					
13		eL	4 41 ..					
		F	5 00 ..					
16		P	12 20 07				9,500	China. P faint on NS: not shown on EW.
		PR1	12 24 29					
		S	12 30 41					
		L	12 49 ..	50				
		L	13 00 ..	30				
		F	15 20 ..					
17		P	19 11 03				8,200	
		S	19 20 32					
		eL	19 39 ..					
		L	19 42 ..	18				
		F	19 55 ..					
25		e	11 53 30					Time corrections uncertain.
		S	11 59 *ca.*					
		eL	12 26 ..					
		F	13 *ca.* ..					

* Trace amplitude.

TABLE 2.—*Instrumental reports, December, 1920*—Continued.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 7		S?	15 33 50					
		L	16 07 ..	28				
		L	16 11 ..	22				
		L	16 18 ..	18				
		F	16 40 *ca.*					
10		P	4 38 12				8,900	
		S	4 48 16					
		L	5 05 ..	45				
		L	5 10 ..	30				
		L	5 22 ..	15				
		F	7 20 *ca.*					
11		P?	21 26 58				3,100	
		S	21 32 46					
		L?	21 34 ..					
		L	21 41 ..	18				
		F	22 10 *ca.*					
13		P	4 11 37				4,100	
		S	4 17 30					
		eL	4 22 10					
		L	4 36 ..	40				
		L	4 38 ..	30				
		L	4 50 ..	16				
		F	5 30 *ca.*					
16		P	12 19 45				9,100	China; times of phases estimated as minute marker was not working. P on both components.
		S	12 30 00					
		PR	12 23 45					
		F	17 30 *ca.*					
16		eL	22 02 ..	30				Decreasing gradually.
		L	22 20 ..	16				
		F	23					
17		P	19 10 49				9,000	
		S	19 21 ..					
		L	19 38 ..	35				
		L	19 50 ..	18				
		F	20 50 *ca.*					Lost in micros.
25		P	11 51 10				5,700	
		S	11 58 32					
		eL	12 30 ..	20				
		L	12 40 ..	15				
		F	14 05 *ca.*					

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 16		$PR1_N$	12 24 14	4				This interpretation adopted after comparison with Honolulu record.
		$ePR1_E$	12 25 00					
		L_E	12 51 20	50				
		L_N	13 02 38	26				
		M_N	13 10 10	18		2,150		
		M_E	13 11 40	17	2,100			
		C_N	13 22 ..	16				
		C_E	13 27 ..	16				
		F_N	14 08 ..					
		F_E	14 25 ..					

CANAL ZONE. *Panama Canal, Balboa Heights.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 8		P_E	6 49 13				85	Direction unknown; generally felt.
		P_N	6 49 41					
		S_E	6 49 53					
		S_N	6 49 54					
		M	6 49 57		*4,000	*3,000		
		F_E	6 51 00					
		F_N	6 52 05					
10								Slight disturbance between 4:35 and 5:30 from distant movement; direction and distance unknown.
16		P_N	12 25 38				6,400 *ca.*	Probably S. or SW. Preliminary phases not on E-W.
		S_N	12 33 44					
		L_N	12 39 24					
		M_E	13 22 00		*4,000			
		M_N	13 25 02			*3,000		
		F_E	14 33 00					
		F_N	14 48 00					

* Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 16		S_N	12 30 25					China.
		eL	12 46 ..	50				
		L	12 55 ..	30				
		L	13 00 ..	20				
		M_E	13 06 ..		*48,000			
		F	14 30 ..					

* Trace amplitude.

CANADA. *Dominion Observatory, Ottawa.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5		$e?_E$	10 30 30					Faint record, almost lost in micros.
		eL_E	10 37 18					
		L_E	10 39 30	20				
		F						Lost in micros.
7		eL	15 34 00	17				Two short records of L waves of small amplitude; balance obscured by micros.
		eL	15 51 30	23				
		F	Micros.					
10		O	4 26 19				9,020	Quakes reported from Honduras about this date, but no trace appears on records.
		iP_V	4 38 33					
		iS_N	4 48 45					
		eL_{NE}	5 05 42					
		L	5 12 ..	24				
		L	5 25 ..	19				
		L	5 35 ..	16				
		F	6 00 ..					
11		O	21 25 41?				(2,470)	Very irregular micros of considerable magnitude obscure the record.
		$(P)_N$	21 30 45					
		$(S)_N$	21 34 48					
		$(eL)_E$	21 36 54					
		L	21 41 ..	22				
		F	22 *ca.*					
13		$e?_E$	4 19 25					
		eL_E	4 39 ..	40				
		L_E	4 52 ..	21				
		L_E	5 02 ..	16				
		F						Lost in micros.
16		O	12 06 45				9,590	Ottawa and Saskatoon define epicenter 41° N. 62.5° E., but arcs are almost parallel and long value poorly defined; epicenter occurred 41° N. but farther east; approx. 41° N. and 85° E., with possibility of center being even farther east.
		P_{NV}	(12 19 27)					
		S	12 30 06					
		e_E	12 37 13					
		i_N	12 38 04					
		eL_E	12 46 ..	60				
		L_N	12 52 ..	45				
		L	13 07 ..	25				
		L_E	12 52 ..	36				
		L	13 20 ..	18				
		L	13 36 ..	17				
		L	13 55 ..	16				
		L	14 12 ..	15				
		LR1	14 17 ..	20				
		L	14 40 ..	18				
		L_E	14 55 ..	18				
		F	16					Last hour's record very faintly marked.
		SASKATOON RECORD.						
		O	12 05 56				9,600	
		P_N	12 18 39					
		S_N	12 29 19					
		$SR1_N$	12 35 25					
		eL_N	12 44 ..					
		M_N	12 56 ..					
		F	15 *ca.*					
17		e_E	19 20 50					Not well recorded; probably occurred in Albania.
		eL_E	19 39 ..	35				
		L_N	19 48 18	20				
		L	20 00 ..	17				
		F	20 15 ..					
25		e_E	12 03 ..					
		eL_E	12 17 30	13				
		L_E	12 20 30	23				
		L	12 30 ..	18				
		L	13 10 *ca.*					

TABLE 2.—*Instrumental reports, December, 1920*—Continued.

CANADA. *Dominion Meteorological Service, Toronto.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5		eL	10 40 42					
		M	10 43 48		*600			
		F	11 18 12					
7		L	15 33 42					Continuous L. waves of short periods.
			to 41 00		*300			
		L	15 52 06					Do.
			to 56 48		*200			
		L	16 25 54					Do.
			to 30 42		*200			
10		?eS	4 49 06					
		S	4 52 12					
		eL	5 01 00					
		eL	5 12 24					
		eL	5 14 36					
		L	5 25 42					
		eL	5 30 12					
		M	5 30 30		*1,000			
		L	5 42 18					May be a dual quake.
		eL	6 11 42					
		Lrep	6 48 24					
		Lrep	7 19 00					
		F	7 23 00					
11		S	21 34 24					S. not well defined and small amplitude.
		SR?	21 35 42		*200			
		iL	21 40 36					
		M	21 42 36		*1,000			
		eL	21 46 36					
		F	22 08 00					
13		e	4 42 18					
		eL	4 47 30					
		eL	5 03 00					
		M	5 04 18		*300			
		eL	5 06 18					
		F	5 19 42					
16		PR?	12 29 18					Real P. not recorded.
		S	12 30 18					
		SR1	12 31 36					
		SR2	12 34 24					
		SR3	12 39 00					
		i	12 45 00					Initial L. waves difficult to interpret.
		i	12 47 00					
		I?	12 48 00					Group of L. sets in amp. 5 to 10 mm.
		eL	12 49 06					
		L	12 51 48					
		iL	12 56 12					
		M1	13 00 48					
			to 02 48		*44,000?			Principal group sets in.
		M2	13 07 48					
			to 08 48		*48,000?		9,625?	Approx. epicenter lat. 47 N., long. 114 E., or 42 N. and 141 E.
		M3	13 13 06					
			to 18 00					
			to 26 18		*25,000?			
		iL	13 54 24					
		L	14 16 00					
		L	14 55 48					
		Lrep	15?40 00					
		Lrep	15?48 00					
		F	16 57 00					
17		eL	19 35 54					Eq. reported from Mendoza, Argentina, at 2.57 and 3.29 p. m.; also quake reported from Albania.
		L	19 45 12					
		eL	19 50 06					
		L	19 52 24					
		L	19 59 18					
		M	19 53 18		*400			
		F	20 14 00					
25		e	12 22 48					
		i	12 27 24					
		iL	12 29 30					
		iL	12 31 30					
		eL	12 35 18					
		M	12 40 36		*1,300			
		eL	12 59 54					
		F						Micros.

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5		P	10 55 31					P. may be L. phase.
		M	10 57 00		*200			
		F	11 41 45					
5		P	22 26 21					
		L	22 40 30					
		M	22 45 00		*200			
		F	22 51 00					
7		L	15 49 16		*100			Times doubtful; no cut-off.
		F	15 53 10					
7		L	15 59 04		*200			Do.
		F	16 03 40					
10		iP	4 51 58					Sharp easterly movement at 4h 57m 23s; line perfectly straight previous to 4h 51m 58s.
		iS	4 57 23					
		L	5 14 36					
		M	5 18 32		*1,000			
		eL	5 43 09					May be a dual quake.
		eL	5 47 03					
		eL	5 54 57					
		Lrep	6 27 39					
		L	6 38 33					
		Lrep	6 51 15					
		F	7 01 49					
11		L	21 36 43					L. may be S. phase
		eL	21 47 18					
		M	21 51 35		*600			
		F	22 03 57					
13		P	4 05 07					
		S	4 11 33					
		L	4 22 57					
		M	4 29 54		*1,500		3,630	
		F	4 39 20					
16		P?	12 19 27				7,000?	P. waves not distinct and beginning of S. doubtful.
		S	12 25 08					
		SR1?	12 26 44					
		SR2	12 28 22					
		SR3	12 29 10					
		SR4	12 30 22					
		i	12 34 04					
		iL	12 36 50					
		L	12 44 02					Group of L. sets in; principal portion begins.
		L	12 49 20					
		L	12 51 10					
			to 01 30					
		M	12 54 35?		*35,000?			
		L	13 04 32					
		L	13 08 26					
		L	13 18 20					
		L	13 29 14					
			to					
			15 07 14					
		e*Lrep*	15 23 20					
		eL	15 36 14					
		eL	16 09 56					
		F	16 19 12					
			VERTICAL.					
		P	*12 16 30*	*2.5*			*5,330*	Times of S. and L difficult to determine, and minute contacts on smoked paper weak.
		S	*12 23 30*	*6*				
		L	*12 33 00*	*30*				
		M	*12 53 00*	*30*		*50*		
16		L	21 51 43					
		M	21 54 11		*200			
		F	21 58 07					
25		S	11?55 43					
		L	12 02 39					
		i	12 21 22					
		M	12 28 26		*800			
		i	12 30 46					
		F	13 24 28					

* Trace amplitude.

NONINSTRUMENTAL EARTHQUAKE REPORTS, CANADA.

November 8, Joliette Seminary, Quebec, approximate time, 15 h. 25 m.: Several feeble shocks felt, duration 6 to 7 seconds. Window frames trembled.

December 7, Atlin, B. C., approximate time, 4.30 a. m.: One sharp shock followed by tremor which lasted about 15 seconds. Number of persons awakened, direction from south to north.

Reports for December, 1920, have not been received from the following stations:

HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.
KANSAS. *University of Kansas*, Lawrence.
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
NEW YORK. *Canisius College*, Buffalo; *Cornell University*, Ithaca; *Fordham University*, New York.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

SEISMOLOGICAL DISPATCHES RECEIVED AT THE SEISMOLOGICAL STATION, GEORGETOWN UNIVERSITY, WASHINGTON, D. C.

[Associated Press.]

Avlona, Albania, December 5, 1920.—An earthquake occurred in the Tepeleni district to the southwest of this city to-day, rendering 15,000 persons homeless.

The Asama-Yama volcano, situated 90 miles northwest of Tokyo, has been in eruption for several days. Ashes are falling over a wide area.

Valdivia, Chile, December 14, 1920.—The volcano Lanin is reported to be in a state of eruption.

Valdivia, Chile, December 14, 1920.—According to a traveler from Pucón, an earthquake in the Vallarica district began at 11 p. m., December 13, and lasted three hours. No fatalities reported.

Peking, China, December 16, 1920.—An earthquake was felt here at 8:20 p. m. The earth rocked buildings and created much excitement in the hotels and clubs.

Santiago, Chile, December 17.—A dispatch from Pucón, Province of Valdivia, states that the volcano Villarica is still discharging flame and lava and that earth tremors continue.

Santiago, Chile, December 17, 1920.—Strong earthquakes were felt at Mendoza, Argentina, at 2:57 o'clock this afternoon. They were repeated at 3:29 o'clock according to a dispatch received here. No casualties reported.

Paris, December 17, 1920.—Two violent earthquakes visited Algiers, each lasting several seconds.

Rome, December 18, 1920.—New earthquake shocks have completed the destruction of the village of Tepeleni. Twenty persons are reported killed.

Buenos Aires, Argentina, December 18, 1920.—One hundred and fifty persons are reported as killed in an earthquake which occurred yesterday afternoon in the village of La Valle, Province of Mendoza. La Valle was apparently the center of the disturbance. Houses collapsed and crevices were opened in the streets through which hot water gushed forth.

Buenos Aires, Argentina, December 18, 1920.—Minor shocks continue throughout the district, one particularly strong tremor being felt yesterday afternoon at 5:30 o'clock in the towns of San Martin and Rivadavia.

Brindisi, Italy, December 19, 1920.—Advices from Saseno give details of the earthquake which occurred concurrently with the earthquake shocks signaled in America. A number of houses disappeared in a great landslide. Thirty deaths are reported.

Buenos Aires, Argentina, December 20, 1920.—Earth tremors occurred again to-day.

Tokyo, Japan, December 20, 1920.—A wireless message from the island of Yap to-day announces that the most violent earthquake shocks occurred in the vicinity of the island, lasting several days.

Tirana, Albania, December 22, 1920.—Forty-two persons were killed, 200 were injured, and 500 made homeless by the recent earthquake in the Tepeleni district, it was learned to-day.

Tokyo, Japan, December 23, 1920.—A Shanghai dispatch to the Ashia Shimbun reports a terrific earthquake in Kan-su Province on December 16, with casualties estimated at 2,000.

Tokyo, Japan, December 23, 1920.—The continued activity of the volcano Asama is causing alarm. Violent explosions occurred in the crater on Wednesday evening and the country for many miles around was strewn with ashes. The towns around the volcano suffered from heavy earthquake shocks and showers of ashes. It is feared that the loss of life is great.

Rockwood, Tenn., December 23, 1920.—An earthquake of considerable violence accompanied by a rumbling sound was felt here and at other towns as far south as Spring City at 2 o'clock this morning.

Buenos Aires, Argentina, December 24, 1920.—A prospector reports that on December 17, the same day the earthquake occurred in Mendoza Province, he was near to Mount Cavalara. He felt a severe shock lasting 50 minutes which threw him to the ground. Afterwards he discovered a crater emitting incandescent lava, hot water and smoke.

F. A. TONDORF, S. J., *Director*.

TABLE 3.—*Late reports (instrumental).*

ALABAMA. *Spring Hill College, Mobile.*

No earthquakes were recorded at this station during November, 1920.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ALASKA. *U. S. C. and G. S. Magnetic Observatory, Sitka.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 16	....	e_N.....	8 34 32	....	....	....	....	
		e_E.....	8 37 40	....	....	....	....	
		F_N.....	8 42 ..	....	....	....	....	
		F_E.....	8 43 ..	....	....	....	....	
ARIZONA. *U. S. C. and G. S. Magnetic Observatory, Tucson.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 16	....	e_E.....	8 45 14	....	....	....	....	Trace only on NS.
		eL_E...	8 52 33	....	....	....	....	
		M_E....	8 54 02	9	30	....	....	
		C_E....	8 55 20	....	....	....	....	
		F_E....	9 07 ..	....	....	....	....	
HAWAII. *U. S. C. and G. S. Magnetic Observatory, Honolulu.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 1	....	e......	17 11 12	18	....	....	....	
		L......	17 21 36	....	....	....	....	
		M.....	17 33 12	18	*700	....	....	
		C......	17 42 ..	18	....	....	....	
		F......	17 51 ..	....	....	....	....	
6	....	e......	21 33 30	....	....	....	....	Slight record.
		M1....	21 43 00	17	*100	....	....	
		M2....	21 52 00	17	*100	....	....	
		F......	22 02 ..	....	....	....	....	
16	....	P......	8 48 30	....	....	....	....	Slight record; phases not apparent.
		e......	8 53 42	....	....	....	....	
		M.....	9 12 30	17	*100	....	....	
		F......	10 03 ..	....	....	....	....	
29	....	P......	8 17 18	....	....	....	....	
		L......	8 19 42	....	....	....	....	
		M.....	8 20 30	15	*500	....	....	
		C......	8 26 ..	....	....	....	....	
		F......	8 45 ..	....	....	....	....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
MARYLAND. *U. S. C. and G. S. Magnetic Observatory, Cheltenham.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 16	....	eP_N...	8 39 05	3	....	....	....	Phases not clearly marked: ePe faint.
		eP_E...	8 39 03	....	....	....	....	
		e_E.....	8 47 51	....	....	....	....	
		eL_N...	8 53 41	....	....	....	....	
		L_E....	8 53 00	....	....	....	....	
		M_N....	8 53 48	....	....	30	....	
		M_E....	8 53 52	....	50	....	....	
		C_E....	8 55 00	....	....	....	....	
		F_E....	9 02 00	....	....	....	....	
		F_N....	9 05 00	....	....	....	....	
PORTO RICO. *U. S. C. and G. S. Magnetic Observatory, Vieques.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 4	....	P_E....	2 12 38	....	....	....	....	Seems to be near shock.
		e_N.....	2 13 06	....	....	....	....	
		M_E....	2 13 24	....	70	....	....	
		M_N....	2 13 38	....	....	150	....	
		C......	2 16 ..	....	....	....	....	
		F_E....	2 22 ..	....	....	....	....	
		F_N....	2 23 ..	....	....	....	....	
6	....	P_E....	10 45 24	....	....	....	....	Do.
		P_N....	10 45 26	....	....	....	....	
		L_N?...	10 45 52	....	....	....	....	
		M_N....	10 46 08	....	....	400	....	
		M_E....	10 46 14	....	120	....	....	
		C......	10 49 ..	....	....	....	....	
		F_E....	10 54 ..	....	....	....	....	
		F_N....	10 55 ..	....	....	....	....	

EARTHQUAKES FELT IN THE UNITED STATES DURING 1920.

[Consult also chart XV in this issue.]

During the year 1920, 106 separate earthquakes strong enough to be felt by the senses were reported from different parts of the continental United States, as listed in the accompanying table, and graphically represented (a dot each *report*, not for each separate quake) on chart XV at the end of this issue of the REVIEW.

Earthquakes of moderate intensities, V–VI (adapted Rossi-Forel scale), accompanied by slight damage or none at all, occurred in California on January 1, February 9, May 18 and 20, June 16 and 28, September 9, October 5 and 12, and on several days in December; in Washington on January 24 (recorded on the seismographs at Victoria, probably having the epicenter under the Straits of Georgia); in Illinois on May 1; in Missouri on May 1: in Utah on September 18, 19, and November 20 and 25. An earthquake of considerable intensity occurred in the vicinity of Los Angeles on June 22, followed by milder shocks in July; this quake is fully treated by Stephen Taber, *Bull. Seismol. Soc. Amer.*, 10, 129–145, 1920; it was recorded by seismographs throughout the country.

Another quake of moderate intensity and wide extent occurred in Tennessee on December 24; and one is reported to have occurred in the Luray district of Virginia in July. Data concerning these are extremely meager.

Places in the United States reporting earthquakes during 1919.

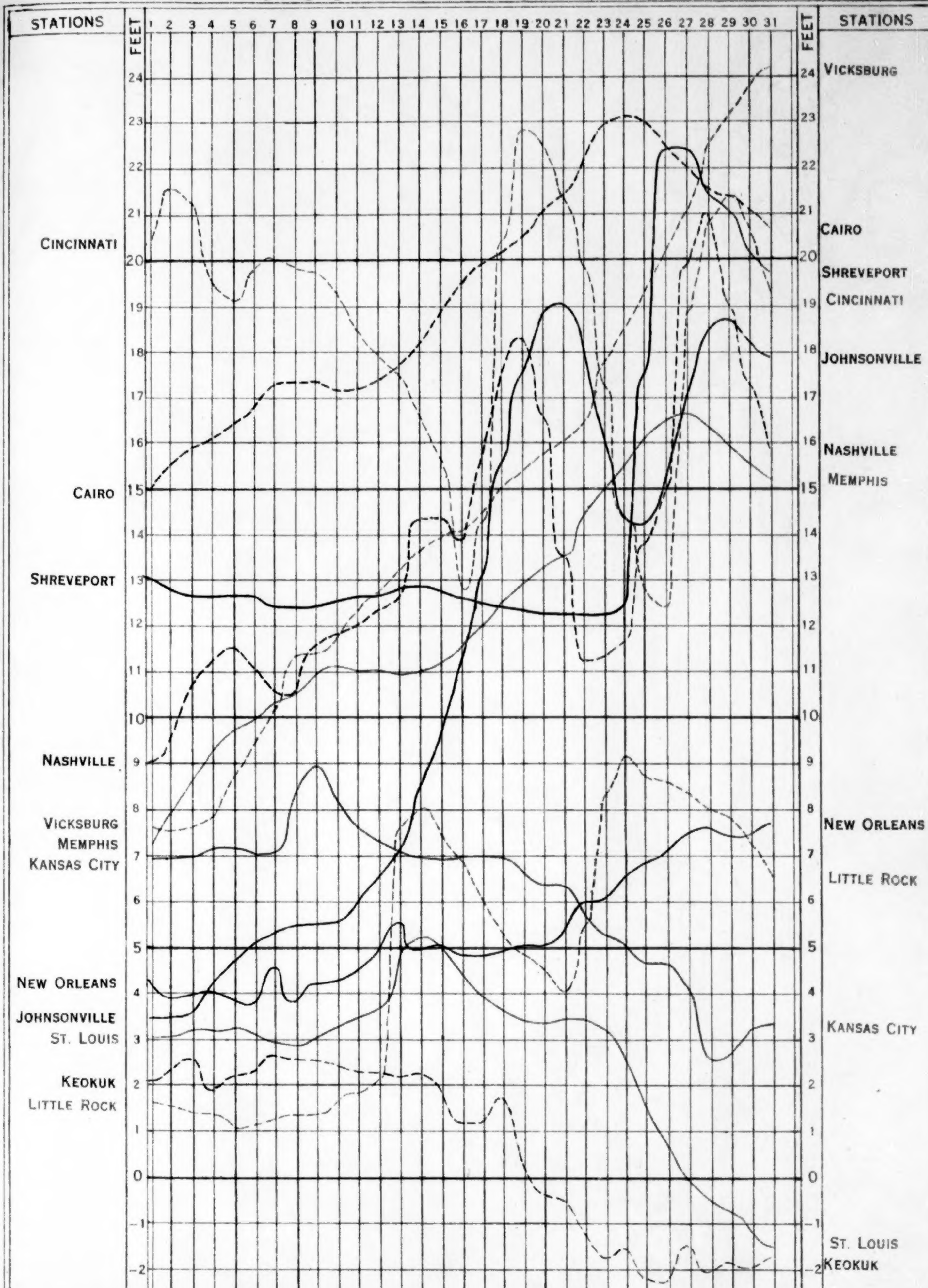
[Consult also chart XV in this issue.]

Place.	Approximate latitude N.	Approximate longitude W.	Number of quakes reported.
CALIFORNIA.			
Aguanga	33 26	116 51	2
Amos	33 05	115 16	3
Avalon	33 15	118 15	1
Barstow	34 54	117 02	1
Blocksburg	40 17	123 39	1
Blythe	33 35	114 45	4
Brawley	32 59	115 40	2
Calexico	32 41	115 30	8
Centerville	37 30	122 00	1
Corona	33 52	117 35	1
El Cajon	32 48	116 58	3
El Centro	32 50	115 35	2
El Segundo	33 56	118 22	1
Elsinore	33 37	117 15	1
Escondido	33 06	117 05	1
Eureka	40 45	124 15	4
Hemet	33 45	116 58	4
Julian	33 05	116 37	3
Kennett	40 45	122 24	1
Lakeport	39 03	122 56	2
Lone Pine	36 37	118 01	1
Los Alamos	34 45	120 15	1
Los Angeles	34 03	118 15	20
Los Gatos	37 12	121 58	2
McCloud	41 15	122 10	1
Manhattan Beach	33 52	118 22	1
Maricopa	35 05	119 23	2
Mesa Grande	33 11	116 42	2
Mount Wilson	34 13	118 16	4
Nellie	33 22	116 52	1
Ojai	34 25	119 12	1
Palo Alto	37 30	122 06	1
Pasadena	34 05	118 10	4
Redding	40 35	122 25	4

Places in the United States reporting earthquakes during 1919—Contd.

Place.	Approximate latitude N.	Approximate longitude W.	Number of quakes reported.
CALIFORNIA—continued.			
Redondo Beach	33 50	118 22	1
Salinas	36 41	121 39	4
San Diego	32 40	117 10	5
San Francisco	37 48	122 25	3
San Luis Obispo	35 13	120 45	3
San Jose	37 15	121 53	2
Santa Barbara	34 23	119 40	8
Santa Monica	34 02	118 30	2
Sprockles	36 38	121 36	6
Taft	35 15	119 30	1
Venice	33 58	118 28	1
Warner Springs	33 15	116 45	4
Whittier	34 00	118 04	1
COLORADO.			
Glenwood Springs	39 30	107 15	1
New Castle	39 30	107 30	3
ILLINOIS.			
Centralia	38 30	89 10	1
Du Quoin			1
McLeansboro	38 07	88 33	2
Mount Vernon	38 20	89 00	1
MAINE.			
Eastport	45 00	67 00	1
MISSOURI.			
Columbia	38 55	92 15	1
Harrisonville	38 45	94 15	1
Springfield	37 10	93 10	1
Warrenton	38 50	91 10	1
MONTANA.			
Helena	46 40	112 00	1
NEW HAMPSHIRE.			
Concord	43 10	71 30	1
OREGON.			
Astoria	46 10	123 50	2
Cascadia	44 15	122 30	1
Crater Lake	42 50	122 00	1
Portland	45 30	122 40	2
SOUTH CAROLINA.			
Summerville	33 05	80 15	2
SOUTH DAKOTA.			
Oelrichs	43 15	103 15	1
Hot Springs	42 30	103 25	1
TENNESSEE.			
Crossville	36 00	85 00	1
Decatur	35 32	84 50	1
Glen Alice	35 50	84 50	1
Rockwook	35 50	84 40	1
Spring City	35 40	84 50	1
Springville	35 52	85 27	1
UTAH			
Beaver	38 12	112 45	1
Brigham	41 30	112 00	3
St. George	37 05	113 30	1
Salt Lake City	40 45	112 00	1
WASHINGTON.			
Anacortes	48 50	122 40	1
Blaine	49 00	122 45	1
Clallam Bay	48 15	124 15	1
Forks	47 56	124 20	1
Glenoma	46 30	122 07	1
Longmire	46 50	121 50	1
Marietta	48 47	122 35	1
Tatoosh	48 23	124 45	1
Detroit	47 20	122 50	1
WYOMING.			
Clark	44.46	109 10	1

Chart I. Hydrographs of Several Principal Rivers, December, 1920.



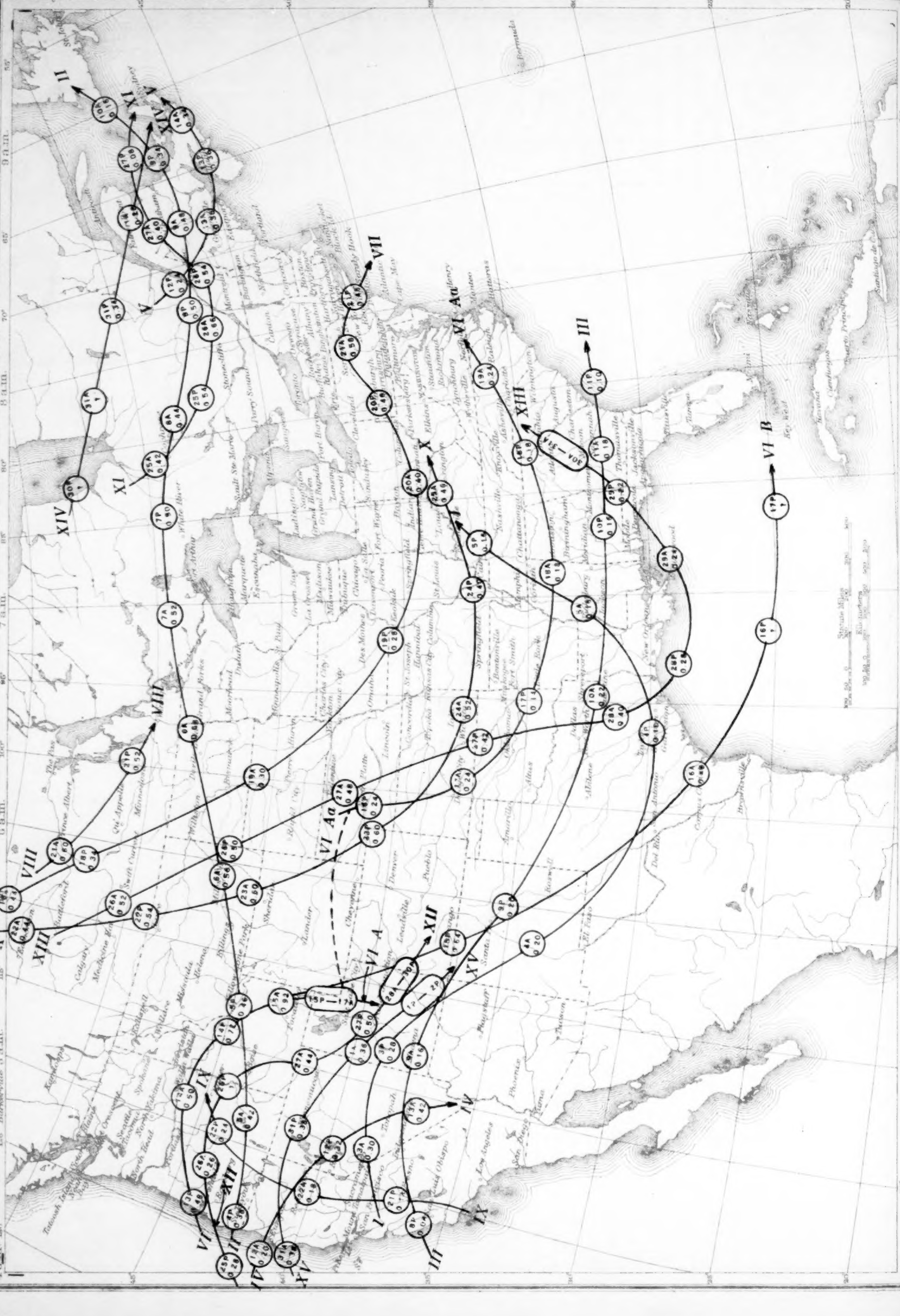


Chart II. Tracks of Centers of High Areas, December, 1920.
(Plotted by Wilfred P. Day.)

Chart III. Tracks of Centers of Low Areas, December, 1920.

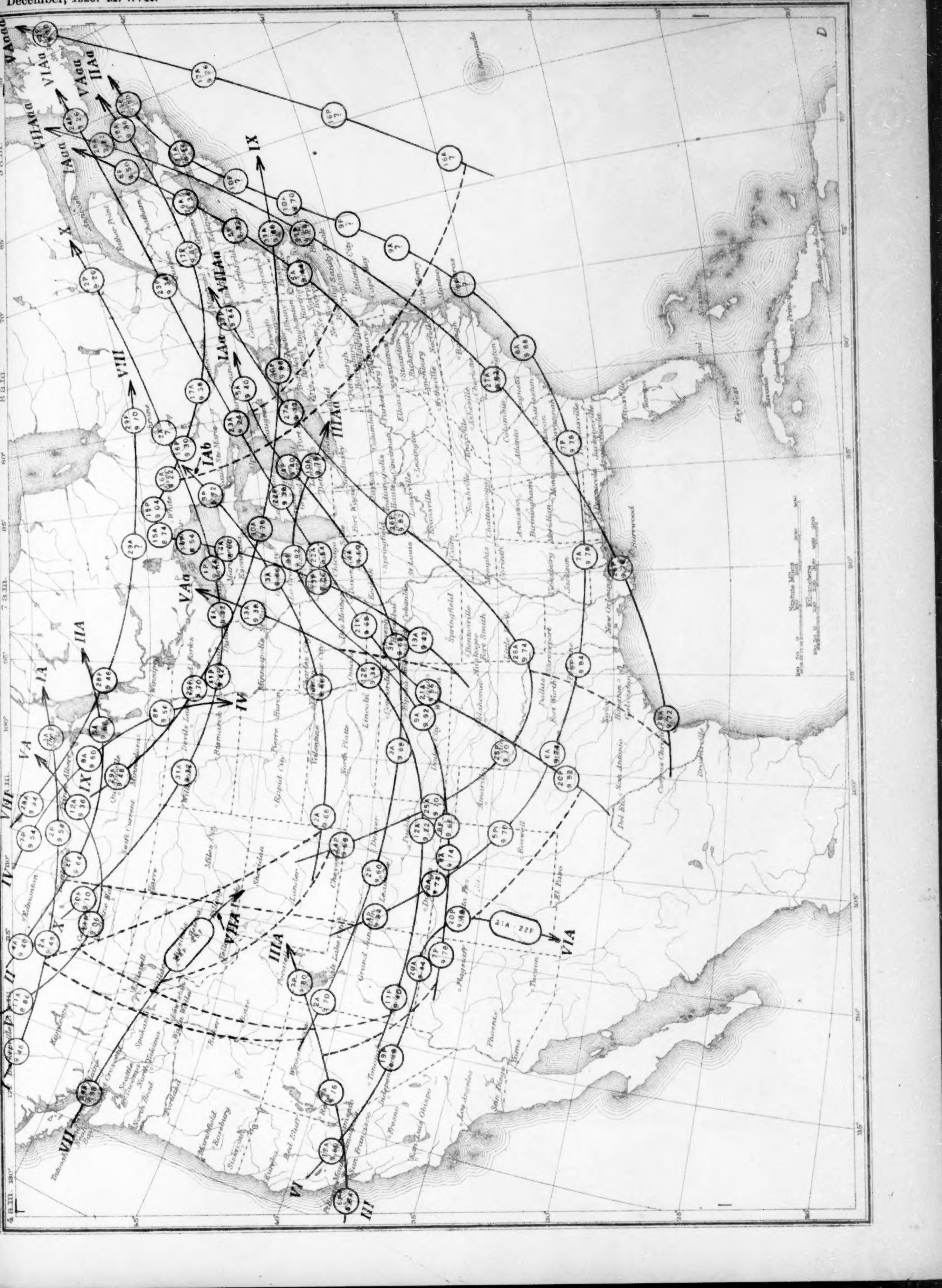


Chart III. Tracks of Centers of Low Areas, December, 1920.
(Plotted by Wilfred P. Day.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, December, 1920.

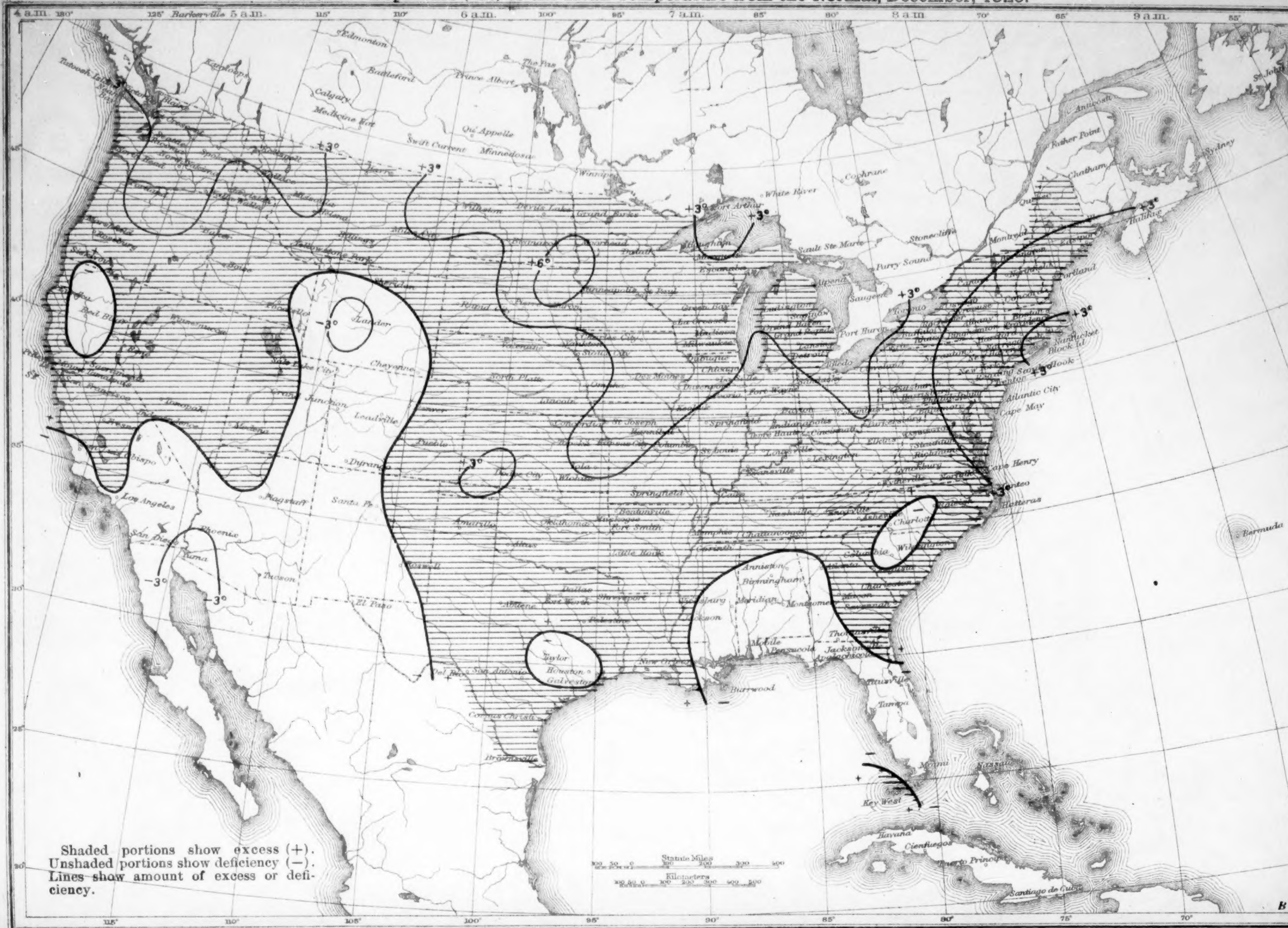


Chart V. Total Precipitation, Inches, December, 1920.

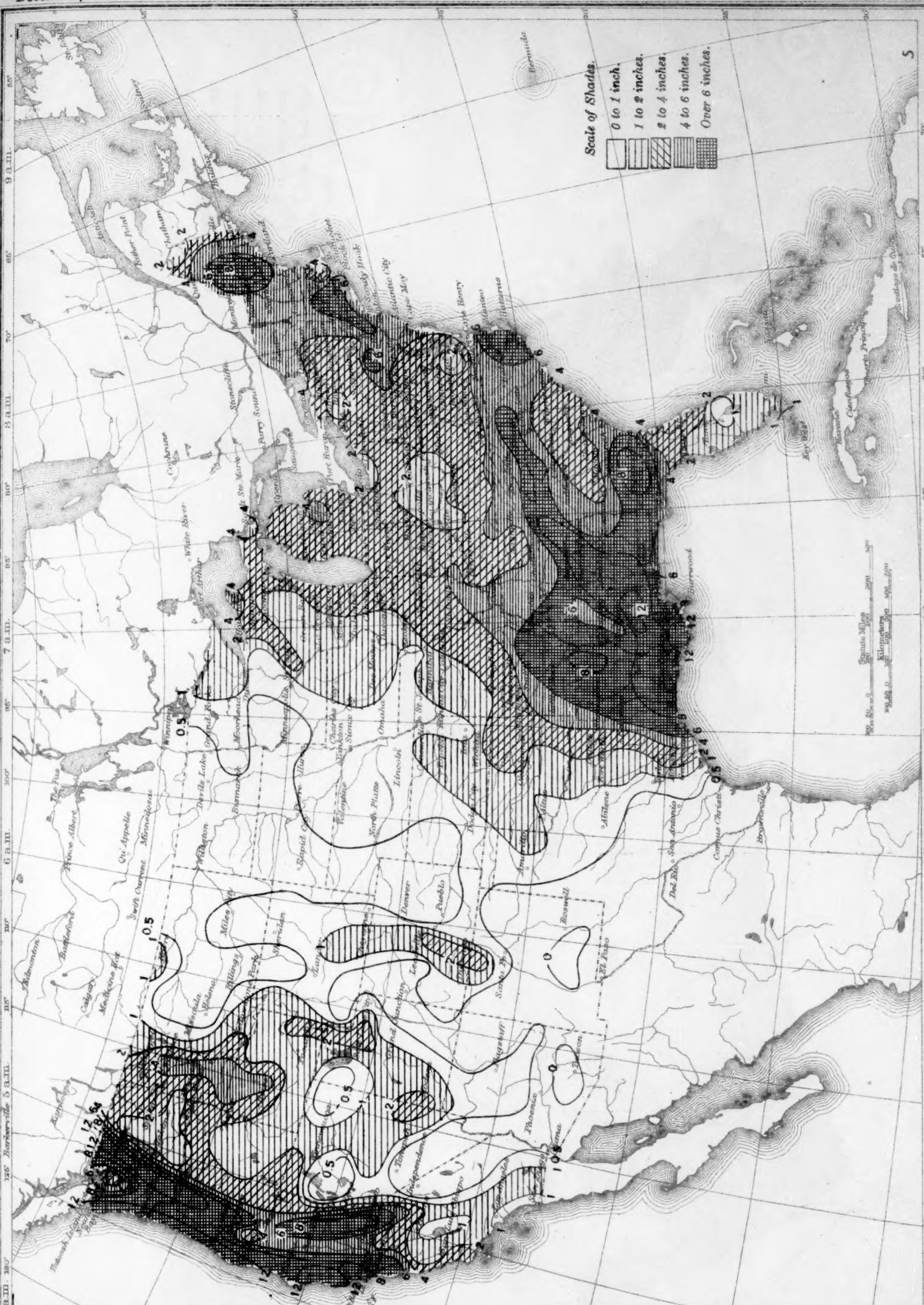


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, December, 1920.

Chart VII. Isobars and Isotherms at Sea-level; Prevailing Winds, December, 1920.

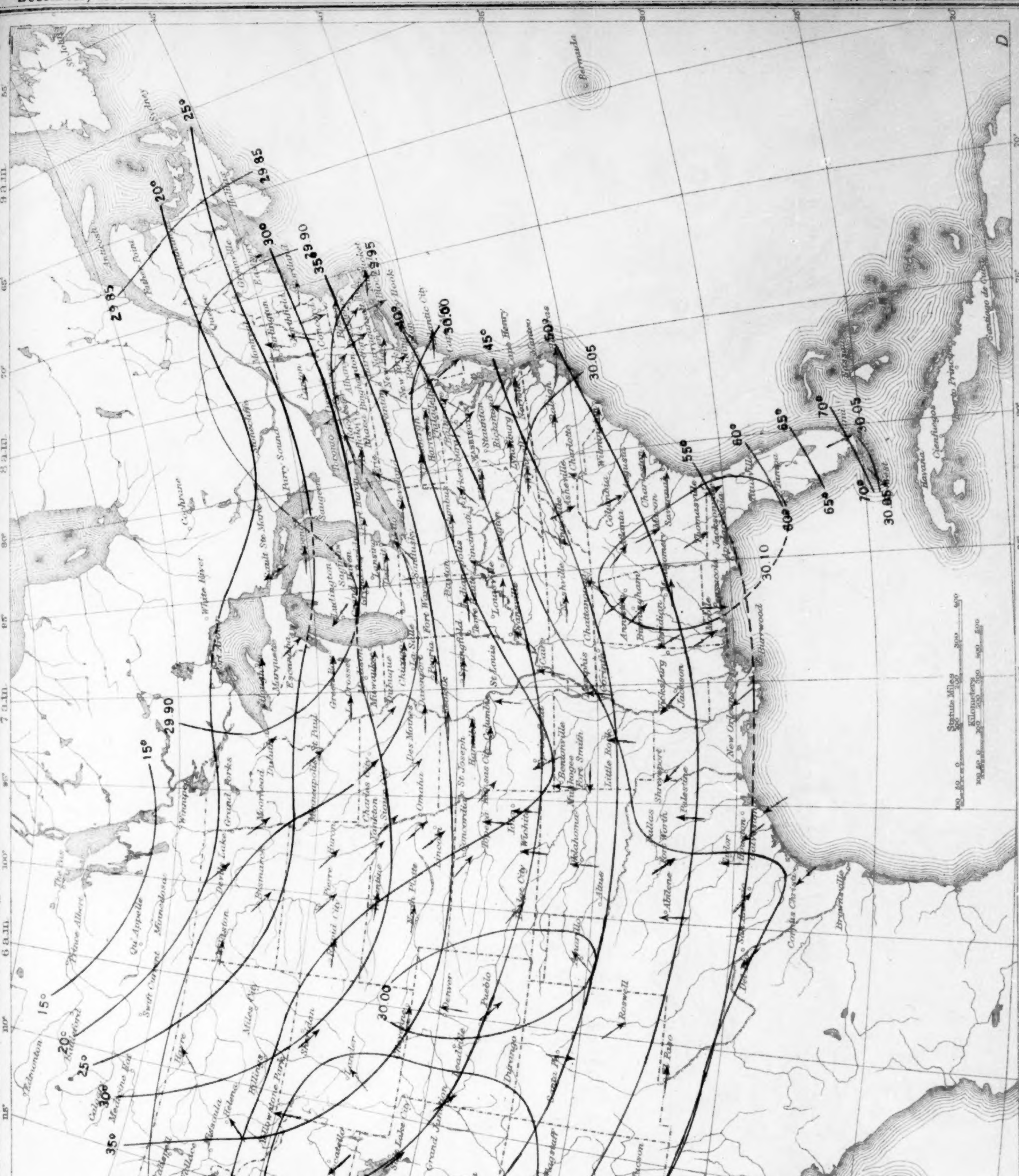


Chart VIII. Total Snowfall, Inches, December, 1920.

Chart IX. Weather Map of North Atlantic Ocean, December 3, 1920.

Chart IX. Weather Map of North Atlantic Ocean, December 3, 1920.
(Plotted by F. A. Young.)

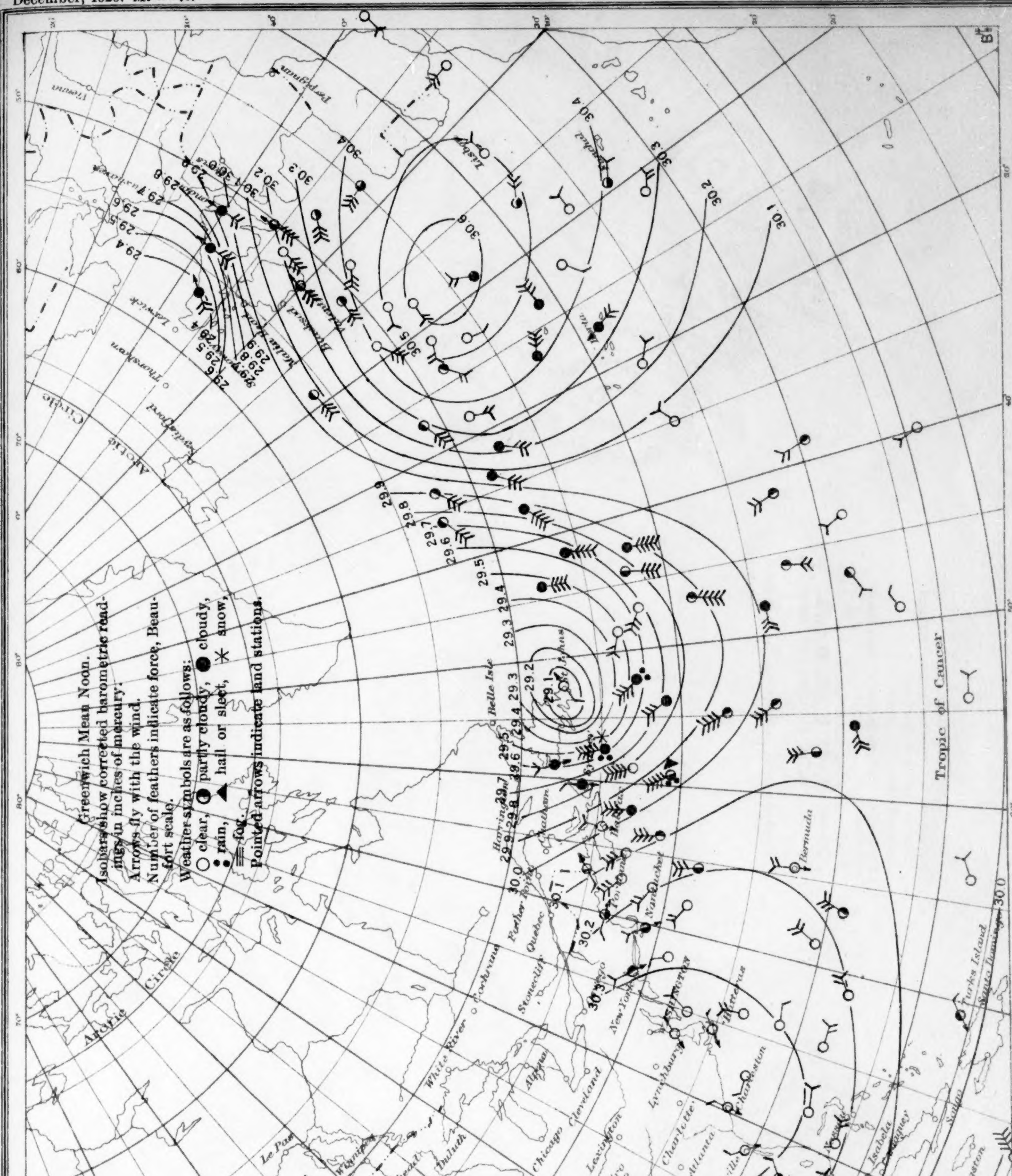


Chart X. Weather Map of North Atlantic Ocean, December 17, 1920.

(Plotted by F. A. Young.)

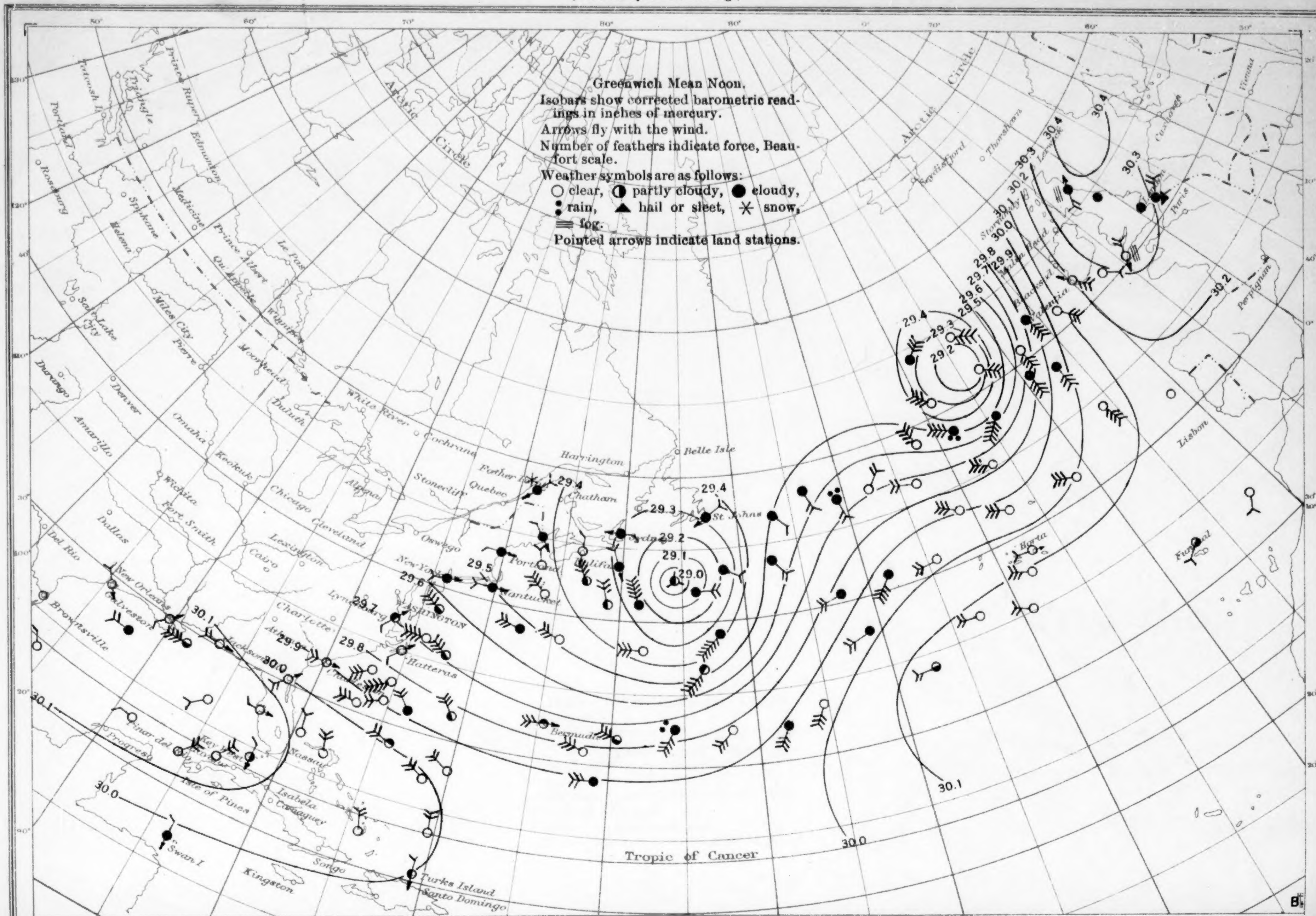


Chart XI. Weather Map of North Atlantic Ocean, December 25, 1920.

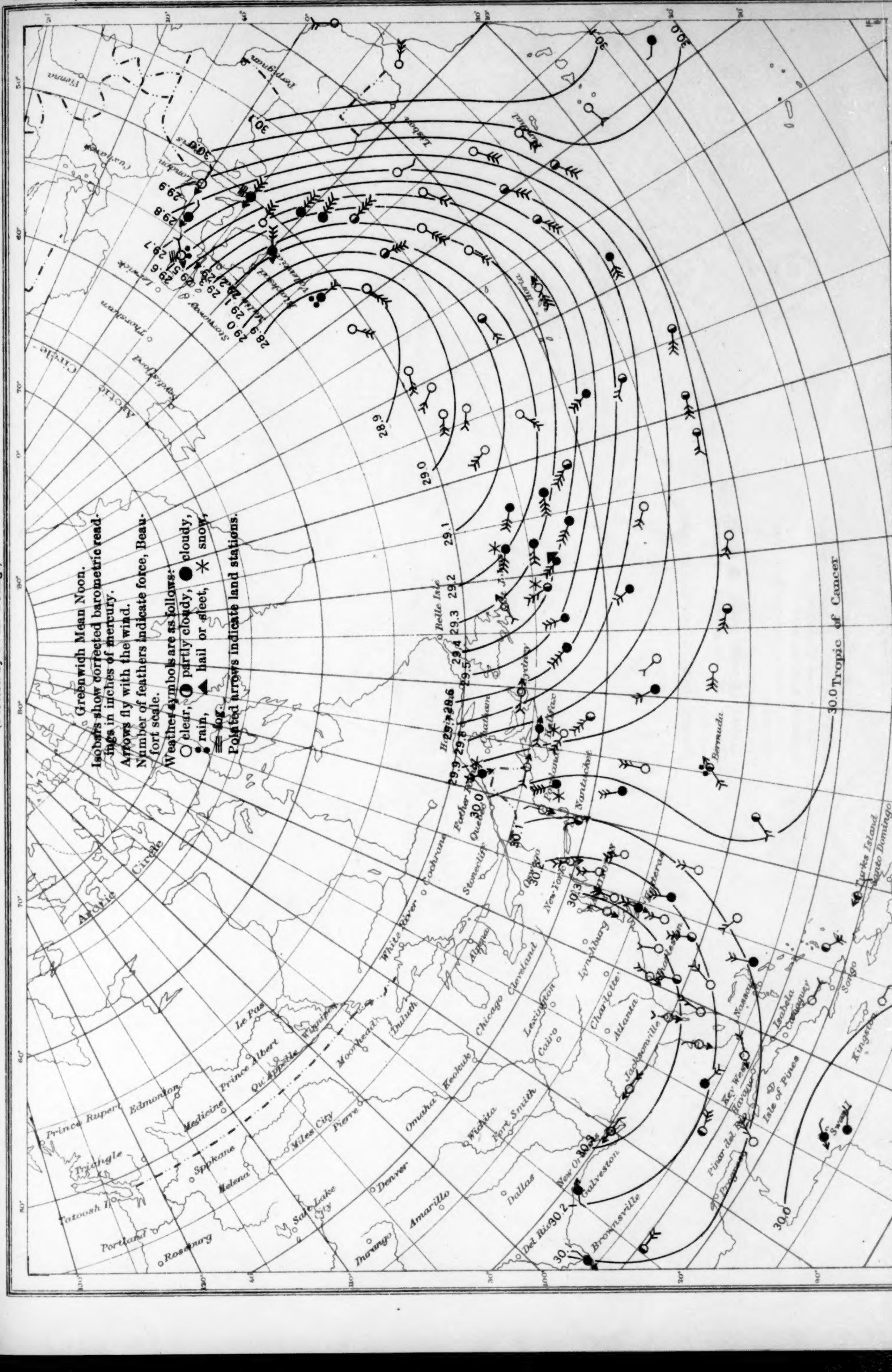


Chart XI. Weather Map of North Atlantic Ocean, December 25, 1920.
(Plotted by F. A. Young.)

Chart XII. Weather Map of North Atlantic Ocean, December 26, 1920.

(Plotted by F. A. Young.)

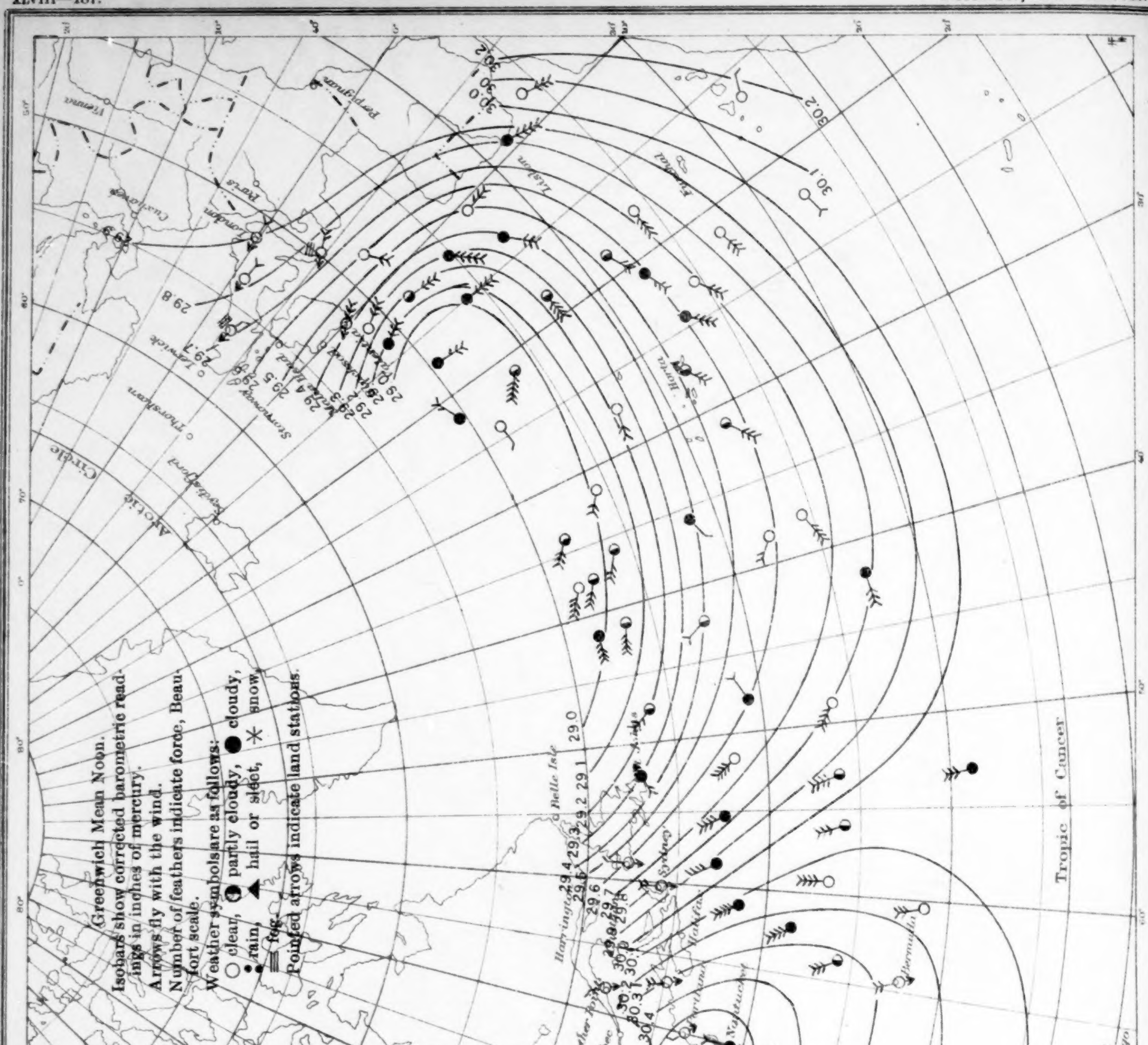


Chart XIII. Weather Map of North Atlantic Ocean, December 27, 1920.

Chart XIII. Weather Map of North Atlantic Ocean, December 27, 1920.

(Plotted by F. A. Young.)

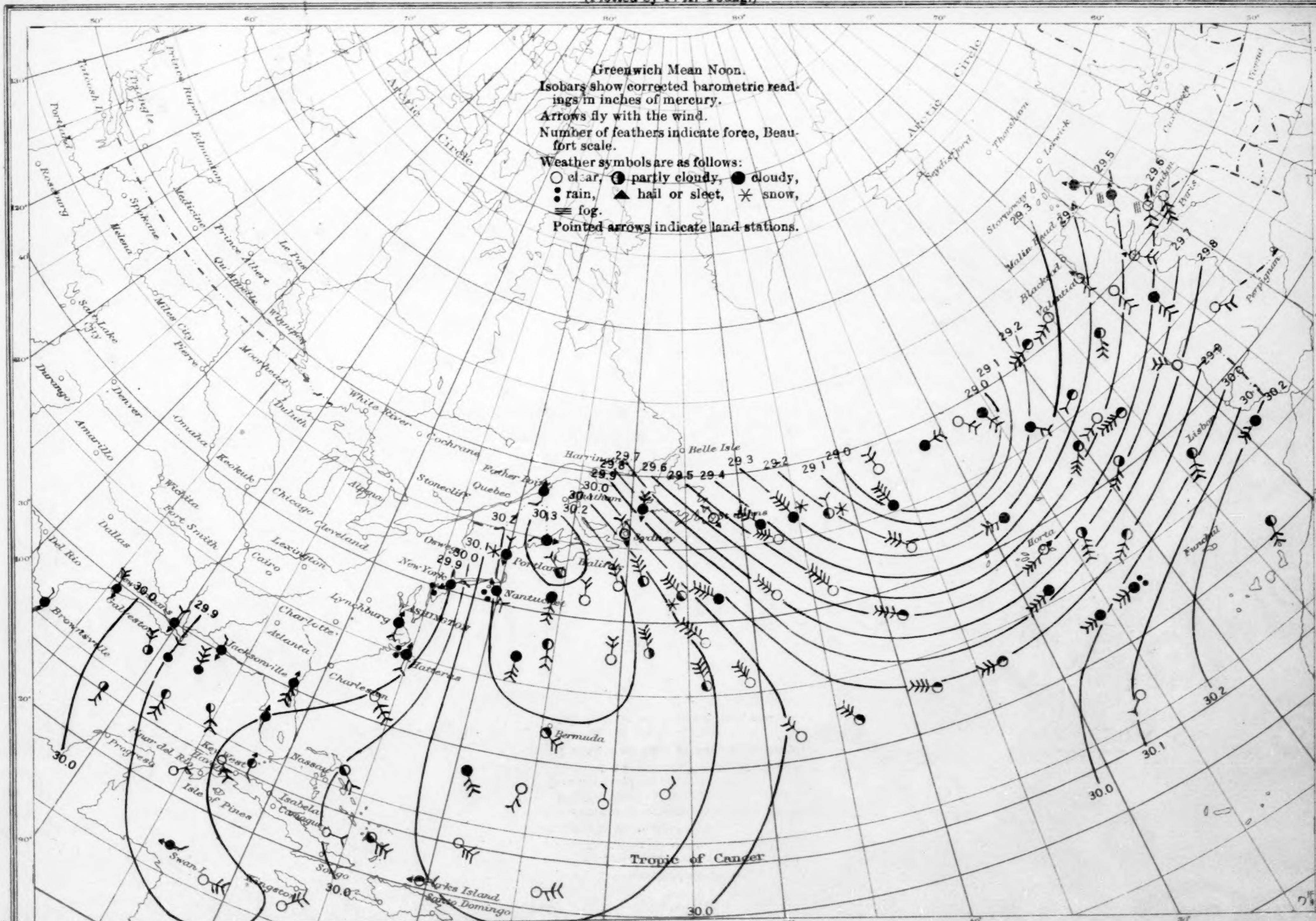


Chart XIV. Weather Map of North Atlantic Ocean, December 30, 1920.

(Plotted by F. A. Young.)

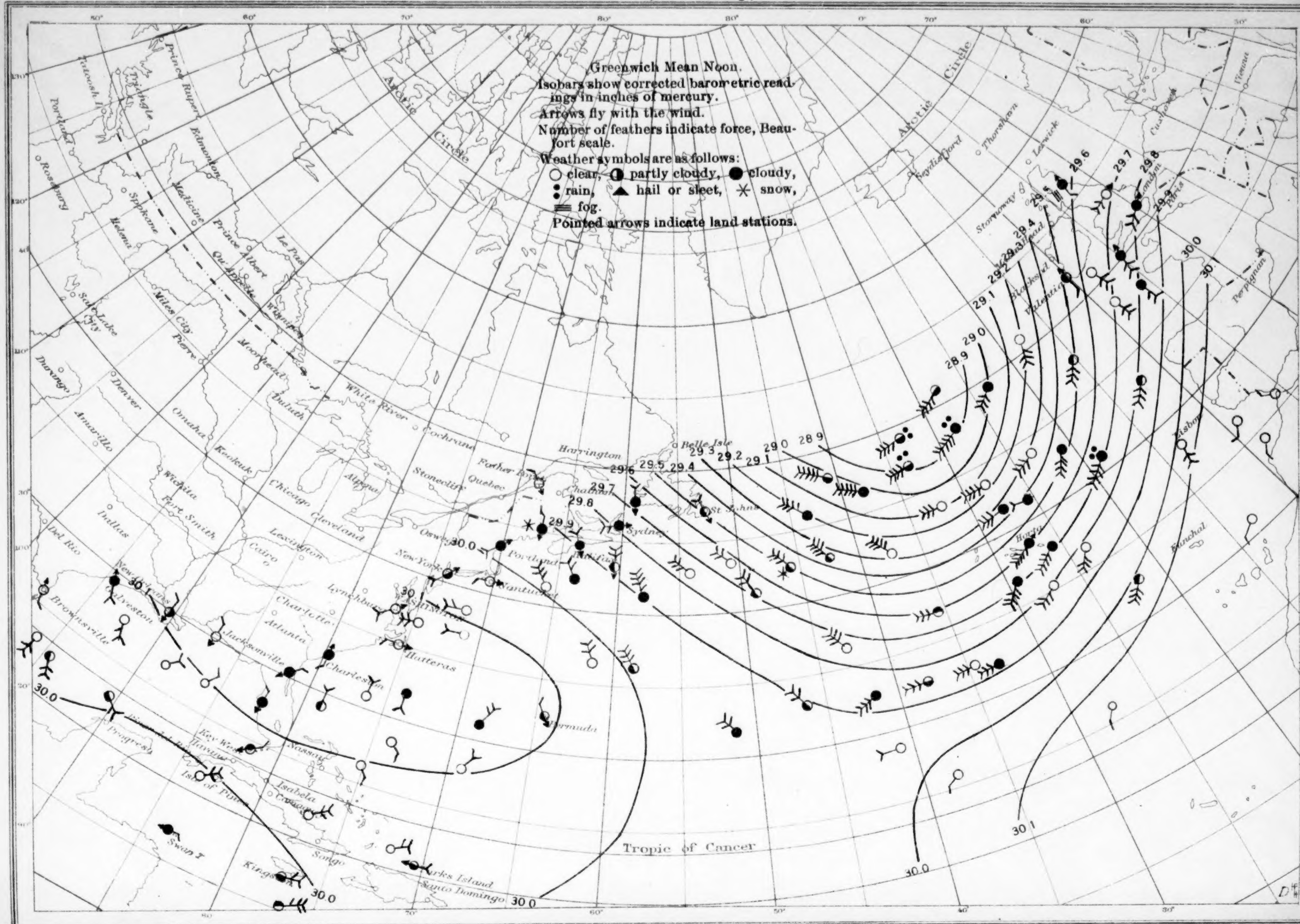


Chart XV. Earthquakes of 1920 in United States.

Chart XV. Earthquakes of 1920 in United States.
(Plotted by E. W. Woolard.)